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USAEC Report No. ENAEC-BC-CR-93112

Final Feasibility Study For Ammunition Demolition Activity Area (OU4) at the Umatilla Depot Activity (UMDA)

Submitted to:

U.S. Army Environmental Center (USAEC),
Aberdeen Proving Ground,
Maryland

Revision 0
November 15, 1993

Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts
02140-2390

ADL Reference 67062

DAAA15-91-D-0016
Delivery Order No. 2

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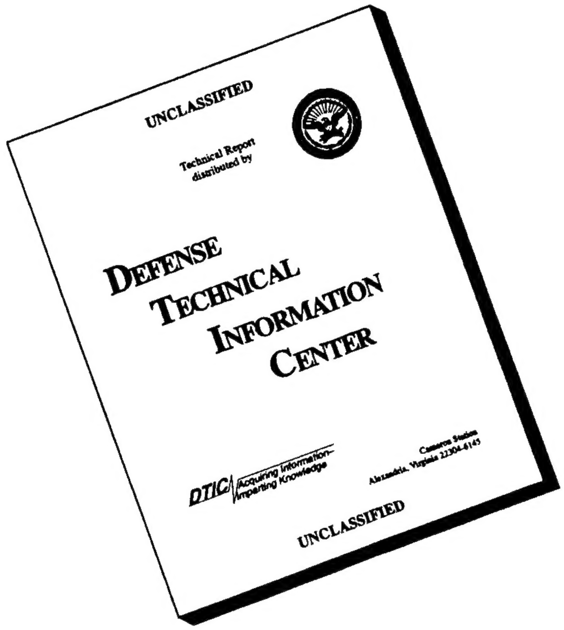

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
November 15, 1993

3. REPORT TYPE AND DATES COVERED
Final 6/92 - 11/93

4. TITLE AND SUBTITLE
Final Feasibility Study for Ammunition Demolition Activity Area (OU4) at the Umatilla Depot Activity (UMDA)

5. FUNDING NUMBERS

6. AUTHOR(S)
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Arthur D. Little, Inc.
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8. PERFORMING ORGANIZATION REPORT NUMBER
67062-45

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Environmental Center
ATTN: ENAEC-BC-A/Bldg. E4480
Aberdeen Proving Ground, MD 21010

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
ENAEC-BC-CR-93112

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

See reverse side of form

14. SUBJECT TERMS
Soil contamination; Metals, Explosives; Unexploded Ordnance; Stabilization/Solidification; Incineration; Containment

15. NUMBER OF PAGES
265

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unclassified/Unlimited

13. Abstract

This report presents the results of the Feasibility Study (FS) performed for the Ammunition Demolition Activity (ADA) Area of Umatilla Depot Activity (UMDA) near Hermiston, Oregon.

From 1945 to the present, ordnance and other solid wastes generated at UMDA were burned, detonated, or otherwise disposed of (by dumping or burial) at the ADA. Twenty sites at which these activities were or are still being conducted, have been identified. As a result of these activities, soil at the ADA is contaminated with a variety of chemical compounds (including explosives and pesticides) and metals. In addition, there are unknown quantities of unexploded ordnance (UXO) on the surface and in the subsurface of the ADA.

This Feasibility Study addresses the contamination of soil at the ADA; develops objectives for soil remediation; and identifies, develops, screens, and evaluates soil remedial action alternatives.

Basic components of the remedial alternatives subjected to a detailed evaluation for contaminated soil at the ADA include: No Action; Institutional Control (with and without UXO clearance); Containment; On-Site Stabilization/Solidification; On-Site Incineration and Stabilization/Solidification; and Off-Site Treatment and Disposal.

An evaluation of remedial alternatives was conducted addressing the response of the alternatives to specific criteria including: Protection of human health and the environment; compliance with Applicable or Relevant and Appropriate Requirements (ARARs); Long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost.

Arthur D Little

Final Feasibility Study for Ammunition Demolition Activity Area (OU4) at the Umatilla Depot Activity (UMDA)

Program Manager, Robert Lambe — Date: 15 NOV 93

Task Manager, Armand Balasco — Date: 15 Nov. 1993

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Distribution /		
Availability Codes		
Dist	Avail and / or Special	
A-1		

Submitted to:

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Acronyms and Abbreviations

ADA	Ammunition Demolition Activity Area
af	Acre Feet
amp	Amperes
APC	Air Pollution Control
ARARs	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substances and Disease Registry
BACT	Best Available Control Technology
BCF	Bioconcentration Factor
BRAC	Base Realignment and Closure
°C	Degrees Celsius
CA	Concentration in Air
CAA	Clean Air Act
CAG	Carcinogen Assessment Group, EPA
CBG/WB	Cemented Basalt Gravel/Weathered Basalt
cfs	Cubic feet per second
CE	Combustion Efficiency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	Conversion Factor
CFR	Code of Federal Regulations
cm	Centimeter
CO	Carbon Monoxide
CRLs	Certified Reporting Limits
CS	Concentration in Soil

Acronyms and Abbreviations

CW	Concentration in Water
CWA	Clean Water Act
DAT	Drill and Transfer
DDD	Dichloro/Diphenyl/Dichloroethane
DDE	Dichloro/Diphenyl/Ethane
DDT	Dichloro/Diphenyl/Trichloroethane
DMRO	Defense Re-utilization Marketing Office
2,4-DNT	2,4 Dinitrotoluene
2,6-DNT	2,6-Dinitrotoluene
DNB	1,3-Dinitrobenzene
DoD	Department of Defense
DOE	Department of Energy
DRE	Destruction and Removal Efficiency
EA	Ecological Assessment
EMPA	Ethyl Methyl Phosphonic Acid
EPA	U.S. Environmental Protection Agency
EPIC	Environmental Photographic Information Center
°F	Degrees Fahrenheit
FFA	Federal Facility Agreement
FS	Feasibility Study
ft	feet
gpm	Gallons per Minute
GB	Non Persistent Nerve Agent

Acronyms and Abbreviations

H	Mustard Chemical Agent
HCl	Hydrochloric Acid
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HMX	High Melting Explosive (octahydro- 1,3,5,7-tetranitro-1,3,5,7-tetrazocine)
HQ	Hazard Quotient
HRS	Hazard Ranking System
ID	Induced Draft
IMPA	Isopypropyl Methyl Phosphonic Acid
in	Inch
IRIS	Integrated Risk Information System
K_d	Soil/Water Partition Coefficient
K_{ow}	Octanol/Water Partition Coefficient
K_p	Permeability Constant
KVA	Kilovolt Amps
lb	Pounds
LD_{50}	Lethal Dose to 50 Percent of the Study Population
LDR	Land Disposal Regulations
M	Million
MAIV	Mechanically Agitated In-Vessel
MCL	Maximum Contaminant Level
µg/g	Micrograms per Gram (parts per million)

Acronyms and Abbreviations

µg/l	Micrograms per Liter (parts per billion)
mg/kg	Milligrams per Kilogram (parts per million)
mg/L	Milligrams per Liter (parts per million)
MSL	Mean sea level
NAAQS	National Ambient Air Quality Standards
NB	Nitrobenzene
NCP	National Oil and Hazardous Substances Contingency Plan
NEPA	National Environmental Policy Act
NOAELs	No Observed Adverse Effect Levels
NPL	National Priorities List
NSR	New Source Review
ODEQ	Oregon Department of Environmental Quality
O&M	Operating and Maintenance
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
OU-1	Operable Unit Number 1 (Inactive Landfills)
OU-2	Operable Unit Number 2 (Active Landfill)
OU-3	Operable Unit Number 3 (Ground Water Contamination from the Explosives Washout Lagoons
OU-4	Operable Unit Number 4 (Ammunition Demolition Activity Area
OU-5	Operable Unit Number 5 (Miscellaneous Sites)
OU-6	Operable Unit Number 6 (Explosives Washout Plant)

Acronyms and Abbreviations

OU-7	Operable Unit Number 7 (Washout Lagoon Soils)
OU-8	Operable Unit Number 8 (Deactivation Furnace and Surrounding Soils)
PA	Preliminary Assessment
PCBs	Polychlorinated Biphenyls
PCC	Primary Combustion Chamber
PIC	Products of Incomplete Combustion
pg/m^3	Picograms per Cubic Meter
PHRED	Public Health Risk Evaluation Data Base
POHC	Principal Organic Hazardous Constituents
PPLV	Preliminary Pollutant Limit Value
PPMW	Parts per Million by Weight
PRGs	Preliminary Remediation Goals
PSD	Prevention of Significant Deterioration
psi	Pound per Square Inch
QA/QC	Quality Assurance/Quality Control
RA	Risk Assessment
RAC	Remedial Action Criteria
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RDX	Royal Demolition Explosive (hexahydro-1,3,5-trinitro-1,3,5-triazine)
RfD	Reference Dose

Acronyms and Abbreviations

RFNA	Red Fuming Nitric Acid
RI	Remedial Investigation
ROD	Record of Decision
RTECS	Registry of Toxic Effects of Chemical Substances
SARA	Superfund Amendments and Reauthorization Act of 1986
SCC	Secondary Combustion Chamber
sec	Second
SF	Slope Factor
SPPPLV	Single Pathway Preliminary Pollutant Limit Value
TBC	To Be Considered
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TSDF	Treatment, Storage, and Disposal Facility
Tetryl	2,4,6-Tetranitro-N-methylaniline
THC	Total Hydrocarbon Concentration
TICs	Tentatively Identified Compounds
TLV	Threshold Limit Value
TOC	Total Organic Carbon
TNB	1,3,5-Trinitrobenzene
TNT	2,4,6-Trinitrotoluene
TSS	Total Suspended Solids
TWA	Time-Weighted Average

Acronyms and Abbreviations

TWA	Total Waste Analysis
UMDA	Umatilla Depot Activity
USAEC	U.S. Army Environmental Center
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
UXO	Unexploded Ordnance
V	Volts
VX	Persistent Nerve Agent
yd^3	Cubic Yards
yr	Year

1.0 Introduction

This report presents the results of the Feasibility Study (FS) performed for the Ammunition Demolition Activity (ADA) Area of Umatilla Depot Activity (UMDA) near Hermiston, Oregon. This report was prepared by Arthur D. Little, Inc., for the U.S. Army Environmental Center (USAEC), formerly the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), under Task Order No. 2, Contract No. DAAA15-91-D-0016. The FS has been conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 and its governing regulations, the National Contingency Plan (NCP) 40 CFR Part 300.

Eight operable units (OUs) have been identified at the UMDA site based on the results of the Preliminary Assessment (PA)[1] and the Remedial Investigation (RI)[2]:

- Inactive Landfills
- Active Landfill
- Ground Water contamination from the explosives washout lagoons
- Ammunition Demolition Activity Area (ADA)
- Miscellaneous Sites
- Explosives Washout Plant (Building 489)
- Washout Lagoon Soils
- Deactivation Furnace and surrounding soils

This FS is focused on the evaluation of remedial alternatives for 20 sites at UMDA that are grouped together as the ADA Operable Unit (OU-4). The other seven UMDA OUs will be evaluated in separate FS reports.

1.1 Purpose and Organization of Report

1.1.1 Purpose

UMDA is a U.S. Army ordnance depot located near Hermiston, Oregon. From 1945 to the present, ordnance and other solid wastes generated at UMDA were burned, detonated, or otherwise disposed of (by dumping or burial) at the ADA. Twenty sites at which these activities were or are still being conducted, have been identified. Each of the sites has been associated with a specific ordnance or solid waste disposal activity.

The risks associated with future exposure to the contaminated soil of the ADA exceed the NCP guidelines and indicate that remediation is required. These risks are based on the release to the public of the ADA area upon closure of UMDA and the restriction of future use of the site for military training and practice operations.

In addition to the chemical contamination of the soil at the ADA, the site is impacted by the presence of unexploded ordnance (UXO) as a result of the ordnance disposal operations that took place. UXO is a significant concern with respect to future use of the

ADA and, as such, factors into the analysis of remedial alternatives and the final selection of the remedial alternative to be pursued.

This FS addresses the contamination concerns at the ADA; develops objectives for soil remediation; and identifies, develops, screens, and evaluates soil remedial action alternatives. Remedial alternatives pertaining to ground water are not addressed in this FS (see Section 1.2.5.4.3, Ground Water at the ADA). However, overall risks for the ADA sites include those relating to exposure to ground water and preliminary remediation goals (PRGs) are identified accordingly.

This FS follows the guidelines provided in the EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* [3], including defining the contamination problems; formulating remedial action objectives for the soil; and developing, screening, and evaluating soil remedial action alternatives. The results of this evaluation will be used by the Army, in consultation with the Environmental Protection Agency (EPA) and the Oregon Department of Environmental Quality (ODEQ), to select and propose a preferred remedial action for the ADA. After the Proposed Plan is reviewed by the public, the Army and the EPA will formalize the soil remedial action decision in a Record of Decision (ROD) document with concurrence from ODEQ. A similar process will be followed for the seven other OUs.

The NCP encourages the evaluation of innovative technologies where they might offer the "potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts... or lower costs for similar... performance than demonstrated technologies" [40 CFR 300.430 (a)(1)(iii)(E)]. As a baseline for these technologies, the impact of taking no action at the site is also presented. Other potentially applicable remedial technologies are discussed in the technology evaluation and screening sections.

The FS is also intended to satisfy the requirements of section 102(2)(C) of the National Environmental Policy Act of 1969 (NEPA). The FS evaluated both the short-term and long-term impacts of several alternatives, including no action. In addition, a NEPA-type public review will take place after completion of the FS and Proposed Plan and prior to issuance of the ROD.

1.1.2 Organization

As the first step in the FS development process, existing data on UMDA and the ADA were compiled, summarized, and interpreted. These data are presented in Section 1.2, Background Information. This background serves to establish an historical and physical perspective of the ADA as well as to provide an understanding of the nature and extent of the contamination. In addition, these data were used as the basis for the conduct of the Human Health Baseline Risk Assessment (RA)[4] which is summarized in Section 1.2.

Based on the interpretations and analyses of site-related data, remedial action objectives were defined and possible general response actions and associated remedial technologies

were identified. The response actions and the remedial technologies were screened; first for general feasibility, and then in more detail on the basis of effectiveness, implementability, and cost. The remedial objectives and the results of the screening procedure are presented in Section 2.4, Identification and Screening of Technology Types and Process Options.

The results of the identification and screening analysis were used to develop remedial alternatives to be carried through detailed analyses. These alternatives consist of individual technologies and process options as well as appropriate combinations of technologies and process options. These alternatives and the rationale used to develop them are presented in Section 3.0, Development of Alternatives.

In Section 4.0, Detailed Analysis of Alternatives, the evaluation of each of the selected remedial alternatives is described. This evaluation addresses criteria specified in the NCP including: overall protection of human health and the environment; compliance with Applicable or Relevant and Appropriate Requirements (ARARs), long-term effectiveness; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; and cost. Following the summary of the response of each alternative to these criteria, all of the alternatives are compared to identify strengths and weaknesses to allow for an informed decision to be made with respect to the selection of the most appropriate alternative to be pursued.

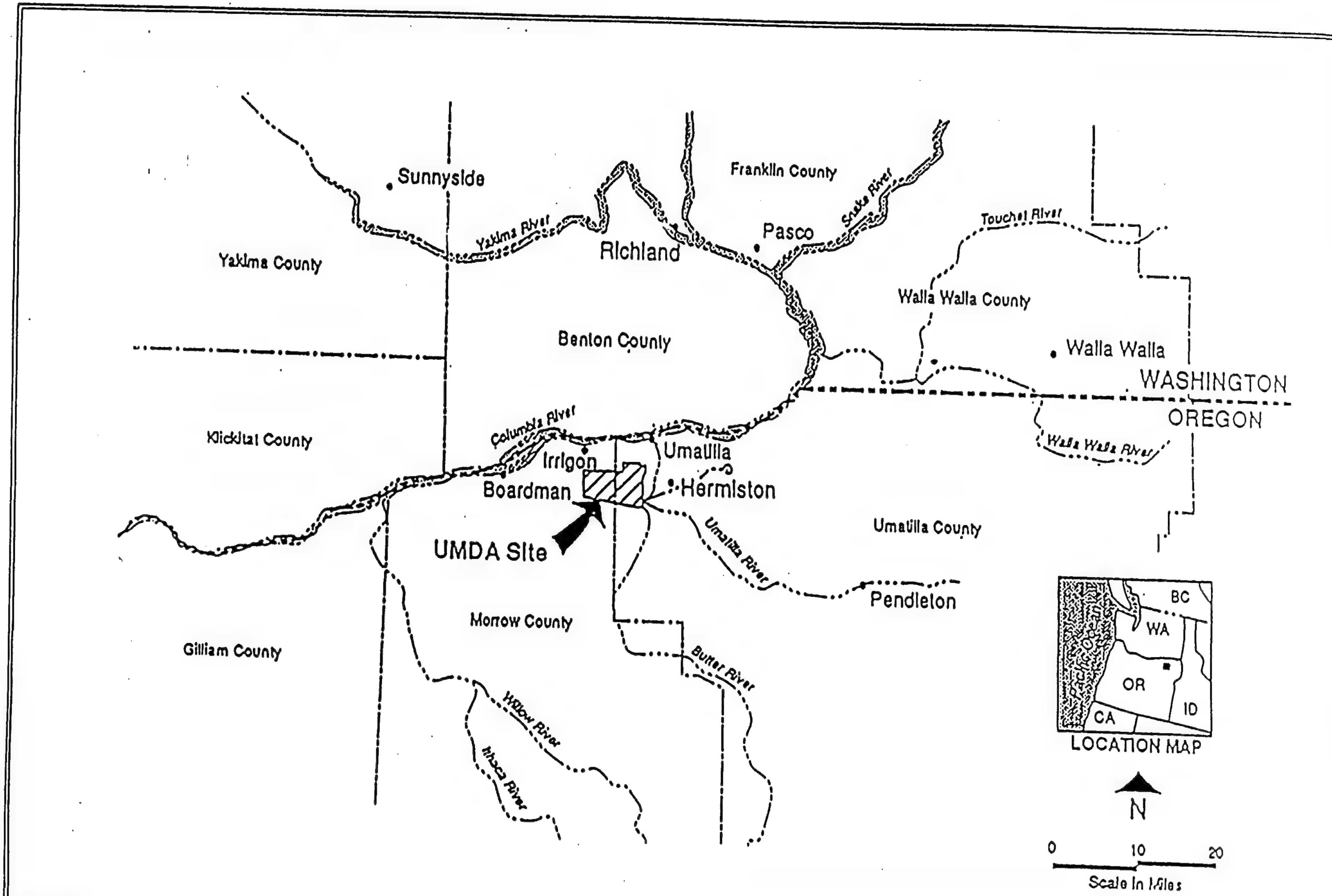
1.2 Background Information

This section describes the background and physical setting of UMDA and the ADA, including the nature and extent of the existing contamination at the ADA sites. The primary references used in developing this background information were the installation-wide Preliminary Assessment[1] and the RI.[2] Also included in this section is a summary of the Human Health Baseline Risk Assessment.[4]

1.2.1 Site Location and History

UMDA is located in northeastern Oregon on the border of Umatilla and Morrow counties, near the city of Hermiston, as shown in Figure 1-1. It was established by the Army in 1941 as an ordnance facility for storing conventional munitions. Subsequently, the function of the facility was extended to include ammunition demolition (1945), renovation (1947), and maintenance (1955). In 1962, the Army began to store chemical-filled munitions and containerized chemical agents at the facility. UMDA continues to operate today as a munitions storage facility, and will be conducting activities associated with the Army's Chemical Demilitarization and Installation Restoration Programs.

The facility occupies a roughly rectangular area of 19,728 acres; 17,054 acres are owned by the U.S. Government, while the remainder are controlled by restrictive easements that provide a safety zone around the facility[2]. Although ownership of the latter is private, the



PREPARED FOR: UMATILLA Washout Plant FS			SOURCE: Umatilla Depot Activity Washout Lagoons Soil Record of Decision (Sept. 1992)	TITLE: Figure 1-1: Facility Location Map Umatilla Depot Activity
DATE: Feb.. 1993	SCALE: AS SHOWN	DWG. NO. 67062-010		

easements grant perpetual rights to the U.S. Government, including the right to prohibit human habitation and to remove buildings. The owners retain the right to farm the lands and to graze livestock.

The UMDA facility is currently one of several installations scheduled for realignment under the Department of Defense (DoD) Base Realignment and Closure (BRAC) program. Under this program, the Army will eventually vacate the installation and relinquish ownership to another governmental agency or private interests. Although future use of the installation in general has not been determined, light industrial or residential use is a possibility. At the ADA a third future use alternative that has been proposed is retention of the site under government control for use in military training.

The ADA is located in the western portion of UMDA. Twenty sites have been identified as areas of historical or current activities at the ADA. The location of these sites are indicated in Figure 1-2.

Activities at the ADA sites consisted of operations to burn, detonate, and otherwise dispose of (by dumping or burial) ordnance and other solid wastes. The types of activities involved a range of chemical compounds and metals, including:

- Explosives contained in ordnance being burned, detonated, or disposed of (2,4,6-trinitrotoluene [TNT]; 1,3,5-trinitrobenzene [TNB]; 2,4- and 2,6-dinitrotoluene [DNT]; nitrobenzene; hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX]; octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine [HMX]; and 2,4,6-tetranitro-N-methylaniline [tetryl])

- Metals (e.g., lead, chromium, antimony, cadmium, copper, mercury, and nickel) contained in ordnance and munition casings being burned, detonated, or disposed of

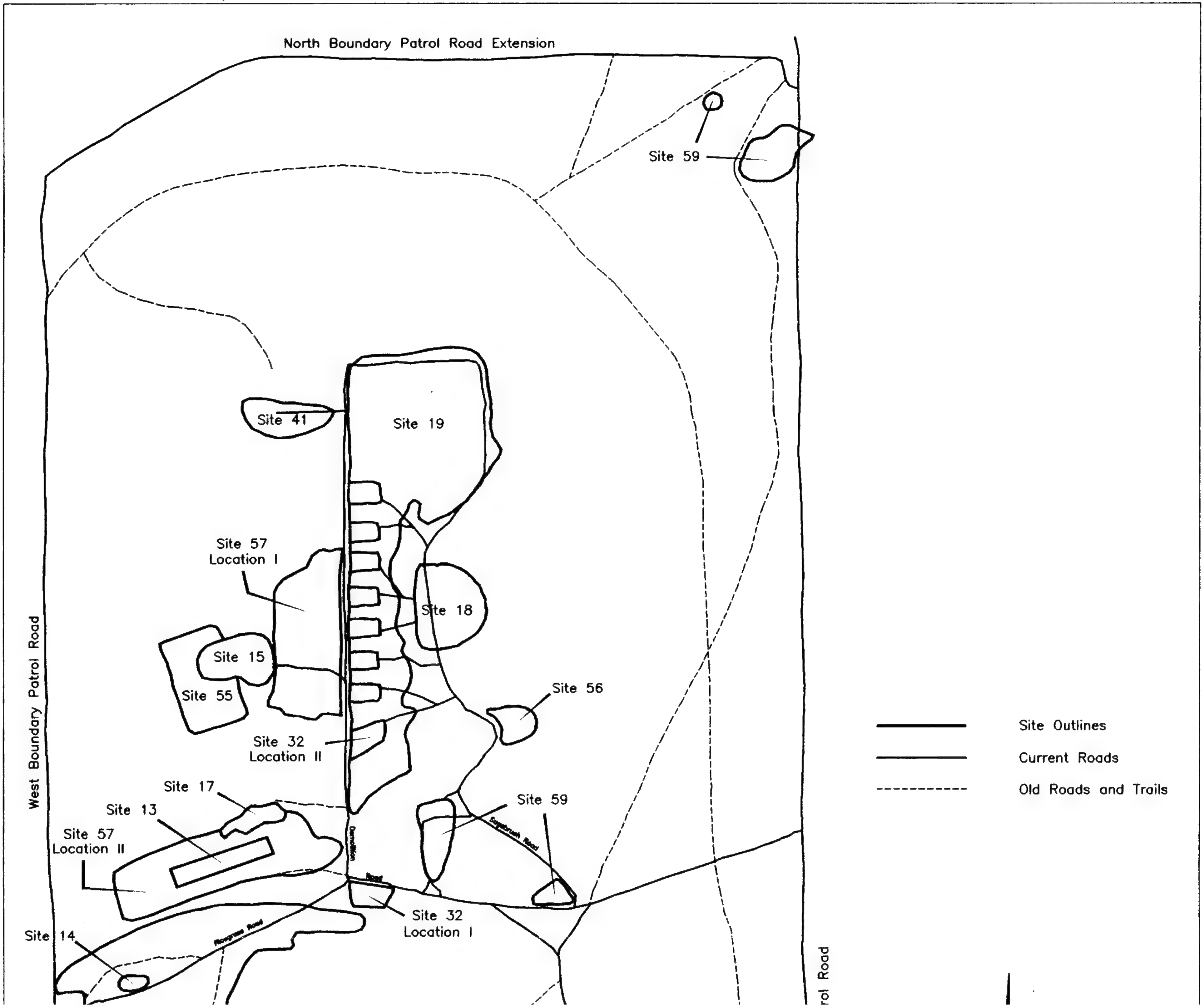
- Pesticides (e.g., DDT, DDE, and dieldrin) applied or disposed of

1.2.2 Site Description

1.2.2.1 Regional and Installation Setting

1.2.2.1.1 Topography and Surficial Geology. The portion of Oregon within an approximate 50-mile radius of UMDA includes parts of two geomorphic regions:[5] the Deschutes-Umatilla Plateau and the Blue Mountains (Figure 1-3). Both of these regions lie at least partly within the Umatilla River Basin.

The Deschutes-Umatilla Plateau has relatively little relief. It gradually rises southward from elevations near 260 feet above mean sea level at the Columbia River to approximately 800 feet at the foot of the Blue Mountains. Near-surface deposits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West Boundary Patrol Road
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Site 19
Site 57
Location I
Site 18
Site 15
Site 55
Site 56
Site 32
Location II
Site 17
Site 13
Site 57
Location II
Site 59
Sagebrush Road
Demolition Road
Site 32
Location I
Site 14
Site Outlines
Current Roads
Old Roads and Trails

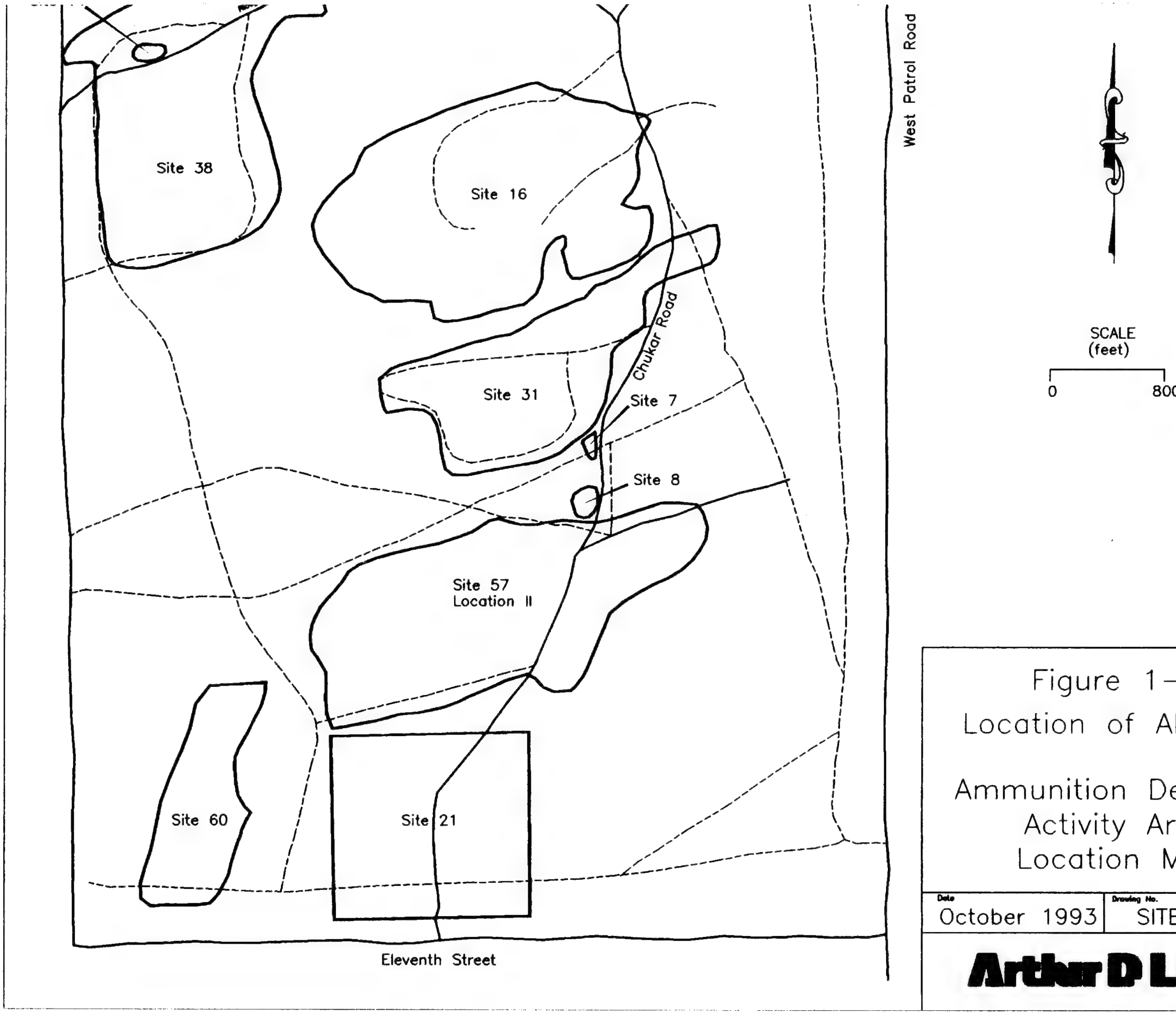

Figure 1-2
Location of ADA Sites

Ammunition Demolition
Activity Area
Location Map

Date	Drawing No.
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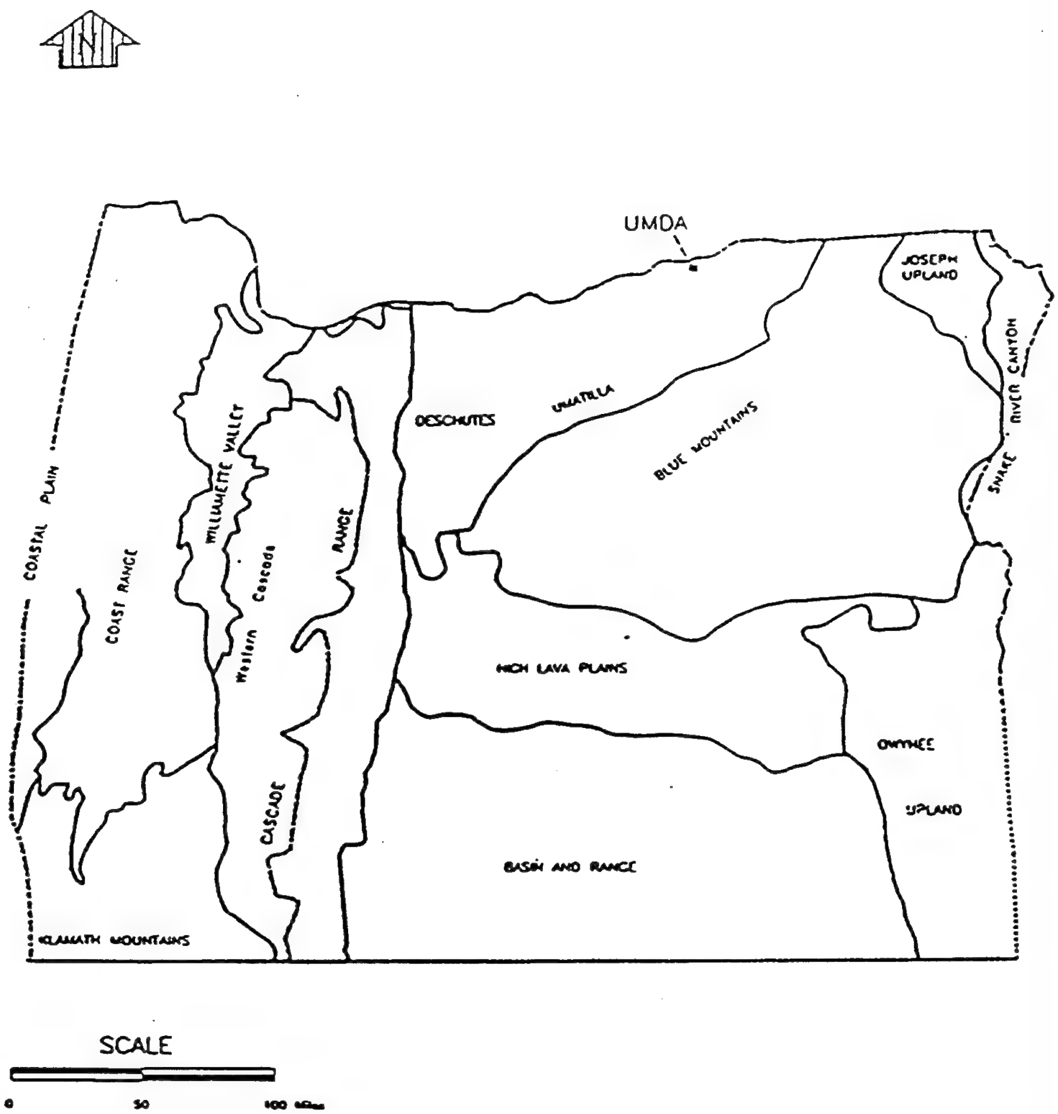


Figure 1-3: Geomorphic Regions of the Area near UMDA. UMDA lies within the Deschutes - Umatilla Plateau.

TITLE FIGURE 1-3: GEOMORPHIC REGIONS OF THE AREA NEAR UMDA		
PREPARED FOR: UMATILLA	SOURCE: AFTER WALKER, 1977, AS MODIFIED FROM DICKEN, 1950	
DATE: OCT. 1992	SCALE AS SHOWN	DWG. NO 67062-014

underlying the Plateau consist primarily of Miocene basalt flows, basalt debris and silts deposited as alluvial fans, Quaternary silts and clays, and Quaternary alluvial gravel and sand deposited by catastrophic flooding of the Columbia River.[5]

The edge of the Blue Mountains lies approximately 40 miles south and southeast of UMDA. The Blue Mountains reach elevations ranging from 3,500 to 6,000 feet. The mountains are considerably dissected by streams, which have eroded many steep-walled canyons.[6] Near-surface deposits are primarily basalt and rhyolitic tuffs, with smaller areas of metamorphosed sedimentary and volcanic rocks of probable Triassic age, and diorite and other intrusive rocks of provable Cretaceous age.

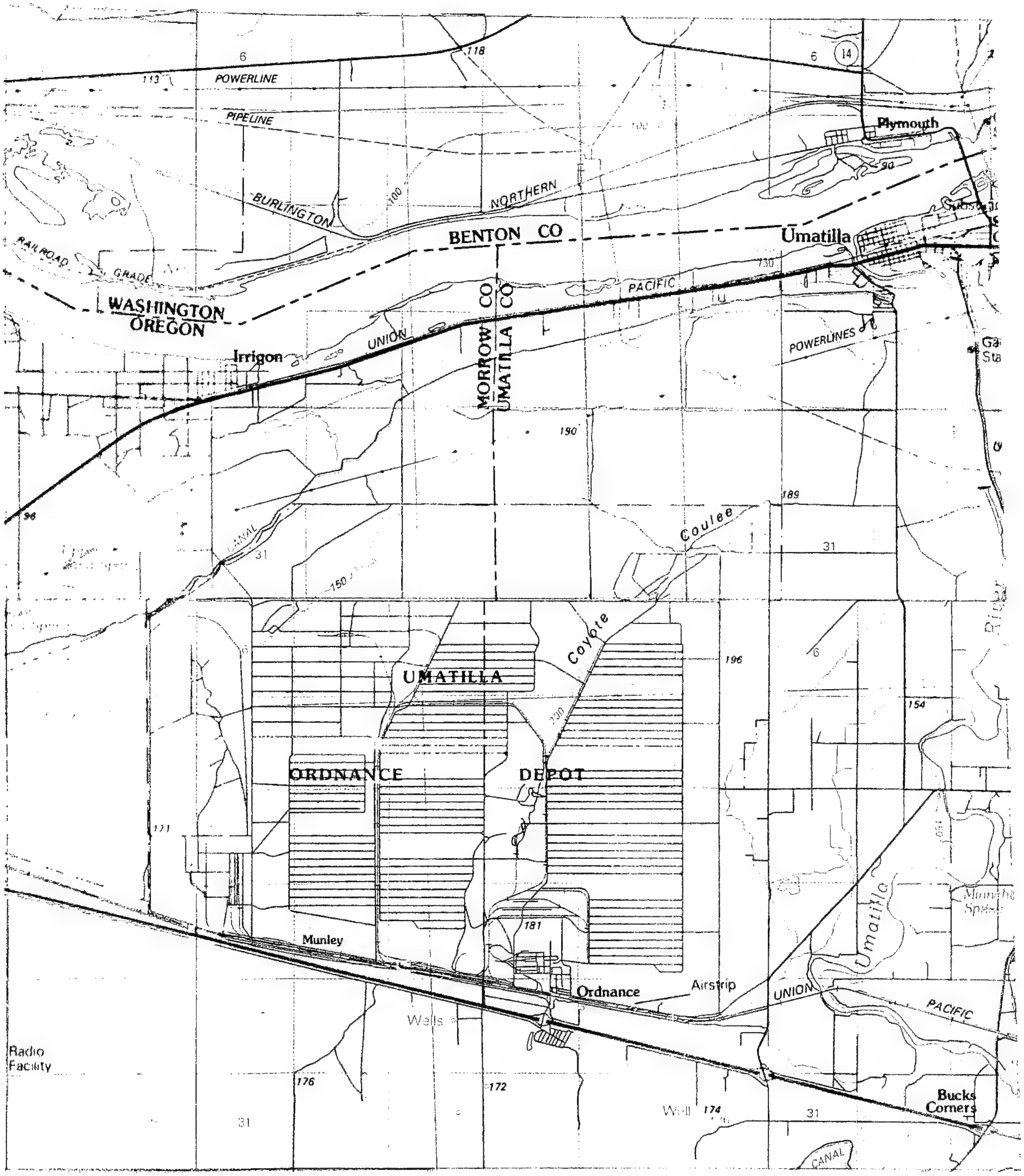
The topography of the UMDA site, illustrated in Figure 1-4, can be naturally divided into three areas: Coyote Coulee; sloping lands east of the coulee; and rolling hills west of the coulee.

Coyote Coulee is a linear depression, about 0.25 mile wide, that trends north-northeast to south-southwest across UMDA. About one-third of UMDA lies east of Coyote Coulee. The east side of the coulee is a steep escarpment about 50 feet high. Although the land rises westward from the bottom of the coulee, the top of the escarpment is at a higher elevation than any nearby land west of the escarpment along most of the length of the coulee. The coulee is thus asymmetrical, unlike an erosional canyon where the elevation of the top of both canyon walls is generally the same. The top of the escarpment is near 650 feet in the north half of UMDA, but slopes southward to 600 feet near the southern boundary. The escarpment vanishes quite abruptly at the southern boundary.

East of Coyote Coulee, the surface slopes smoothly to the southeast, away from the escarpment, at a slope of approximately 50 feet per mile (ft/mi). The principal exceptions are a low hill near the southeast corner of UMDA, and a nearly level area around the administration area. West of Coyote Coulee, the surface consists largely of rolling hills. The highest hill (677-foot elevation) is near the northern boundary, just west of Coyote Coulee. A broad area of high ground extends to the southwest from this hill; from the high ground, the surface slopes, with many irregularities to the northwest and south.

The northern half of the area west of Coyote Coulee has many linear hills and valleys, trending east-northeast to west-southwest, 10 to 20 feet high and up to 0.5 mile in length. These features may be large ripples associated with catastrophic flooding that occurred during drainage of Glacial Lake Missoula.

No natural streams occur within UMDA because of highly permeable soil. Drainage patterns are very poorly developed because of highly permeable soil, low precipitation and the recent formation of the landscape. No direct information on storm water drainage is available for most of UMDA. Storm water runoff apparently does not travel far, except near the administration area, where runoff is collected by storm sewers. Many areas of closed drainage exist, particularly west of Coyote Coulee, with the largest about 100 acres in size.



Note: Horizontal Lines within UMDA area are igloo storage areas.

PREPARED FOR: UMATILLA			Figure 1-4: Topography of UMDA
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The ADA, consisting of approximately 1,750 acres in the northwestern corner of UMDA, is characterized by gently sloping to undulating topography. Elevations range from 400 feet above mean sea level (MSL) to approximately 580 feet above MSL.

Surface water runoff generally follows topography and flows in a north-northwest direction. Drainage patterns are poorly developed. The southeastern corner of the ADA contains topographic depressions that may pond surface water for short periods of time.

1.2.2.1.2 Stratigraphy. This section provides an overview of the stratigraphy of UMDA, discussing only the geological units investigated by drilling during the RI and previous on-post investigations as well as a recently completed post-RI investigation[8]. The geology of the ADA conforms to the stratigraphy of the UMDA region.

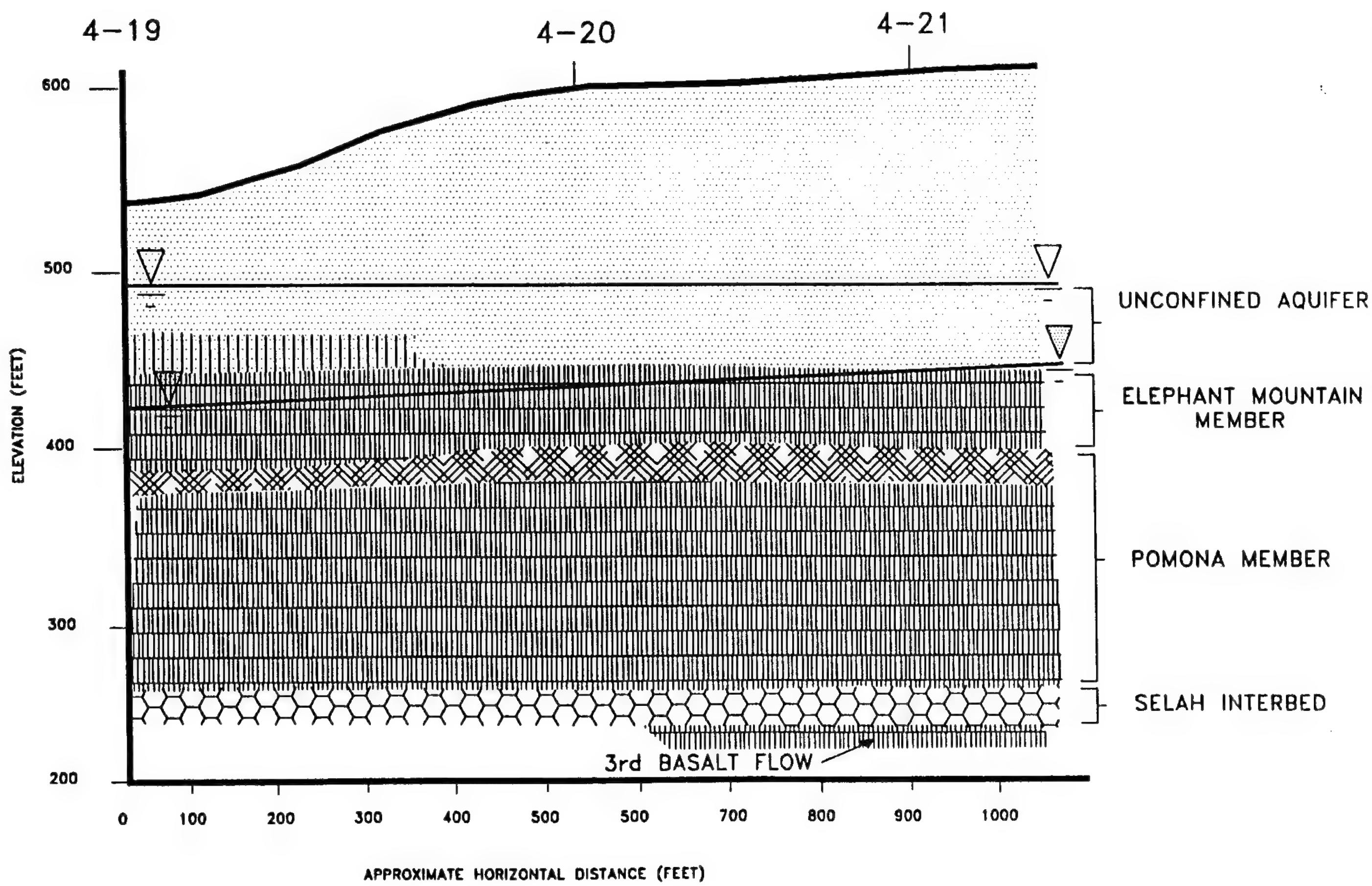
As described in the RI, three distinct geologic units underlie UMDA. These are, from oldest to youngest, unweathered to moderately weathered basalt flows and associated interbed deposits of the Columbia River basalts; "cemented basalt gravel/weathered basalt" (CBG/WB) and underlying gravel; and unconsolidated alluvium. However, recent investigations have indicated that the CBG/WB is actually the first basalt layer (Elephant Mountain Member) and represents a confining layer for the Rattlesnake Ridge Interbed as shown in Figure 1-5.

Columbia River Basalt Flows and Interbeds. The unweathered to moderately weathered basalt flows and associated interbed deposits are lithologically consistent (but not homogeneous), and laterally continuous across UMDA. In general, the tops of the basalt flows are moderately weathered, vesicular, and highly fractured. This zone grades downward to less weathered, massive basalt with fewer fractures. The base of the basalt flows is relatively sharp. Permeable interbed deposits lie between the massive basalt flows. The interbeds are much thinner than the basalts and are derived from weathered basalt gravel and possibly other sedimentary materials It is difficult to distinguish basalt-derived sedimentary interbeds from weathered flow tops on the basis of drill cuttings and video logs.

A total of six individual basalt flows and associated interbeds have been penetrated by on-site wells. The first unit, informally referred to as the CBG/WB in the RI, has been determined to be the Elephant Mountain Member in the post-RI investigation. The Elephant Mountain Member is underlain by approximately 30 feet of basalt-derived unconsolidated sands and gravels, which is the Rattlesnake Ridge Interbed. These gravels appear to be distinct from the overlying flood-deposited alluvial gravels, which are generally more rounded and contain a greater variety of source rock types.

The second basalt flow is the thickest encountered, having an approximate thickness of 170 feet. This unit is interpreted to be the Pomona Member of the Saddle Mountain Basalt, based on stratigraphic characteristics and position in geologic sequence. This basalt flow is underlain by a thinner interbed horizon, which is interpreted to be the Selah

Figure 1-5



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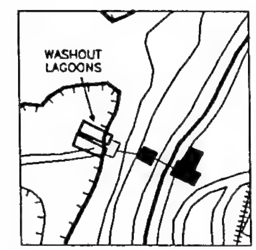
EXPLANATION

- ALLUVIUM
- SILT AND CLAY
- FLOW TOP
- BASALT
- INTERBED

SOURCE: DAMES & MOORE

LOCUS MAP



SCALE: AS SHOWN

DRAWN BY (INITIALS) M.S.B

APPROVED BY (INITIALS)

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Interbed of the Ellensburg Formation. The four deep monitoring wells at Site 4 are completed in this interbed. Where fully penetrated on UMDA, the thickness of the Selah Interbed ranges from 20 to 70 feet.

The Selah Interbed is underlain by another basalt flow and associated interbed, which are interpreted to be the Umatilla Member of the Saddle Mountain Basalt and the Mabton Interbed of the Ellensburg Formation, respectively. Only two water supply wells fully penetrate both the Umatilla Member and the Mabton Interbed; the thicknesses of these units in these two supply wells are approximately 50 and 25 feet.

These two water supply wells also penetrate at least three more thin basalt flows and associated interbeds below the Mabton Interbed. These thin basalt flows are interpreted to consist of the upper portion of the Frenchman Springs Member of the Wanapum Basalt. The Frenchman Springs Member is composed of several individual basalt flows separated by unnamed interbeds of the Ellensburg Formation. A total thickness of over 230 feet of basalt flows belonging to the Frenchman Springs Member and associated unnamed interbeds is encountered in these two deep supply wells.

The top of basalt (i.e., Pomona Member) occurs beneath UMDA at elevations ranging from 300 to 404 feet above MSL, based primarily on the borehole geophysical logs. The top of basalt is relatively flat across most of the installation. However, depths encountered in water supply wells (supply -6 & -7) are significantly deeper, indicating that the basalt dips northward in the vicinity of these wells.

Alluvium. The alluvium consists of unconsolidated clay, silt, sand, and gravel containing cobbles up to at least 6 inches in diameter. These sediments probably represent catastrophic flood deposits or associated lower energy deposits in "quiet" waters. Lithologically, the unconsolidated detritus consists of quartzitic, felsic, and basaltic clasts. Throughout UMDA, sands or gravel are generally encountered at the surface. These deposits tend to become finer grained with depth, typically grading to sandy or clayey silts near the base of the alluvial section at its contact with the CBG/WB. Silt and clay beds up to tens of feet thick occur near the bottom of the alluvium in some parts of the installation (e.g., Site 11). Coarser sands and gravels extend to a greater depth in the southern portion of UMDA, with a layer of silty clays still present above the CBG/WB. The angular basalt gravel underlying the CBG/WB is not considered part of the alluvium, because it appears to be of a different age and origin.

The thickness of the alluvial section penetrated in monitoring wells at UMDA ranges from approximately 42 feet in the northern part of the ADA area to 173 feet at Site 11. In addition, a thickness in excess of 200 feet was estimated in one of the water supply wells based on borehole geophysical logs. Most of this variation is due to differences in surface elevation; the elevation of the base of the alluvium varies less than that of the land surface.

1.2.2.1.3 Hydrogeology. Ground water occurs beneath UMDA in a number of distinct hydrogeologic settings, in a series of relatively deep confined basalt aquifers and in a highly productive permeable unconfined aquifer in the south of UMDA (extending off post). Geologically, the confined basalt aquifers consist primarily of the flow top interbeds between unweathered basalt flow interiors. The basalt flow interiors act as confining layers separating the interbed aquifers; however, structural discontinuities may be present within these flow interiors, providing local, vertical hydraulic connections between flow top aquifers. The unconfined aquifers consist of the saturated permeable alluvium and the saturated silty alluvium. The CBG/WB and the underlying gravels were originally thought to be part of this unconfined aquifer; however, that interpretation has been revised based on post-RI investigations and this layer is now considered to be the Rattlesnake Ridge Interbed. A representative cross section illustrating the major hydrogeologic features of Site 4 at UMDA is presented in Figure 1-5.

Confined Basalt Aquifers. Ground water occurrence in the basalt is primarily within interbed units consisting of gravels and vesicular flow tops lying between basalt flows. Ground water is under confined conditions in these basalt aquifers. Based on borehole geophysical logs of water supply wells; supply-6 and supply-7 (i.e., the deepest on-post wells), as many as five confined aquifers could be present beneath UMDA between ground surface and a depth of 700 feet. However, the four deep basalt monitoring wells at Site 4 and approximately half of the water supply wells penetrate only the uppermost confined aquifer, which occurs in the Selah Interbed. This aquifer appears to be continuous beneath UMDA and to extend beyond the installation boundaries. The lateral extent of the underlying interbeds (confined aquifers) beneath UMDA is largely unknown due to the lack of deep wells that penetrate them.

The interbeds are fairly productive aquifers, yielding 29.5 gpm for a period of eight hours at Site 4 and could have produced more if the pump had been set deeper in the well. Large yields are obtainable from water supply wells that penetrate one or more interbeds. Water supply well supply-1, for example, is capable of producing 1,000 gpm with 10 feet of drawdown[9]. Therefore, this well has a relatively high specific capacity of 100 gpm/ft. Supply-5 and supply-7 have even higher specific capacities, 133 and 130 gpm/ft, respectively, but are limited to smaller yields of 500 and 650 gpm by the capacities of their pumps.

The unweathered basalt flows act as confining beds or leaky confining beds to retard vertical movement of water between the alluvium and basalt interbeds and, apparently, between different interbeds. Structural discontinuities may be present to provide local hydraulic connections between flow top aquifers. The vertical hydraulic conductivity of the basalt has not been measured at UMDA. However, permeability data for flow interiors are available for the Hanford site in Washington[10]. Reported horizontal permeabilities range from 1×10^{-7} to 1×10^{-10} cm/sec. Field-derived vertical

permeability estimates are not available from Hanford. Based on simulations and statistical analyses of fracture data, DOE estimates that vertical permeabilities will be found to be within a factor of 10 of the horizontal conductivities.

Unconfined Aquifer. As previously stated, the unconfined aquifer at UMDA consists of the sand and gravel of the alluvium and the silty clay of the alluvium. Areally, unconfined ground water occurs in two distinct hydrogeologic units beneath UMDA -- a permeable southern aquifer (termed the Ordnance Aquifer) and a less permeable northern aquifer. The behavior of ground water in these two aquifers is distinctly different.

Ordnance Aquifer. The Ordnance Aquifer is located in the southern portion of UMDA and extends off post both to the south and to the east, corresponding to the "Ordnance Critical Ground water Area." To the south of UMDA, the aquifer is tapped by numerous shallow wells that produce as much as 1,000 gallons per minute. Although regional water levels have declined since initiation of irrigation pumping in the 1950s and 1960s, the specific capacities of these irrigation wells are high. The use of the aquifer has been the subject of regional studies to evaluate the impact of withdrawals and artificial recharge activities[10]. Ground water levels in the Ordnance Aquifer have shown a net annual increase since the initiation of artificial recharge activities and reduced pumping in the 1970s.

Permeabilities of shallow wells in the southern part of UMDA (Ordnance Aquifer) are typically much greater than in wells to the north. Average permeability values from wells in the Ordnance Aquifer at Sites 4 and 12 are on the order of 2.1×10^{-1} cm/sec (585 ft/day), with a maximum of 9.6×10^{-1} cm/sec (2,721 ft/day). Ground water gradients within the Ordnance Aquifer are very low (approximately 0.00015 ft/ft), further suggesting high aquifer permeabilities. An evaluation of hydrographs from the Ordnance Aquifer monitoring wells at Sites 4 and 12 shows a significant seasonal response to off-post pumping and artificial recharge activities to the south and east of UMDA.

The saturated thickness of the Ordnance Aquifer is known only at Site 4, where four monitoring wells penetrate through to the Pomona Member. At this site, the saturated thickness of the entire unconfined aquifer ranges from approximately 100 to 127 feet. These estimates include the entire saturated thickness of the alluvium, the CBG/WB, the underlying gravel, and the upper 10 feet of the Pomona Member (which is fractured and moderately weathered).

Ground water flow directions in the Ordnance Aquifer reverse seasonally in response to off-post pumping and recharge activities. During the summer and early fall, flow is toward the east and south as irrigation activities peak. During the winter and early spring, when irrigation activities are at a minimum, ground water flow is to the north and west. It is probable that prior to initiation of irrigation in the 1950s and 1960s the natural direction of flow in the Ordnance Aquifer was to the northwest toward the Columbia River and in the direct vicinity of the Umatilla River, possibly to the northeast. Currently, because water level declines have occurred in the aquifer, discharge is

probably exclusively to irrigation wells. There is likely insufficient head now to drive ground water either into the finer sediments of the northern aquifer or over the top of the finer sediments within the more permeable sediments (which are now dewatered and overlie the finer northern aquifer sediments).

Northern Aquifer. The Northern Aquifer pinches out along an east-west transect slightly north of Site 4. Ground water gradients to the south of this contact are low and reverse seasonally in response to off-post stresses. Ground water gradients to the north of this contact are much greater (0.0085 ft/ft) and show no seasonal reversals. Flow is consistently to the northwest, where it probably discharges to the Columbia River. Hydrographs of selected wells indicate that the wells do not respond to off-post irrigation activities, suggesting that they are not in hydraulic contact with the Ordnance Aquifer. Northern aquifer permeabilities are typically much less than those to the south, with an average value of 9.5×10^{-3} cm/sec (27 ft/day) and a maximum value of 1.8×10^{-1} cm/sec (503 ft/day).

The saturated thickness of the northern aquifer beneath UMDA, exclusive of the Elephant Mountain Member, is about 30 to 60 feet in most places. In the ADA area, the alluvium reaches a maximum saturated thickness of 70 feet; but it is zero in the north, where the elevation of the top of the Elephant Mountain Member is above the water table.

1.2.2.1.4 Streams Within the Umatilla Basin. UMDA is located in the Umatilla Basin. The basin's area is about 2,545 square miles[13]. The principal stream is the Umatilla River, whose principal tributaries rise in the Blue Mountains and flow generally northward toward the Columbia River, which bounds the basin to the north. The Columbia is a major river in the area, with a mean discharge of 200,000 cubic feet per second (cfs)[11]. Its level is stabilized at an approximate elevation of 265 feet by the John Day Dam.

Mean discharge of the Umatilla River (located approximately 1 to 2 miles east of the installation boundary, depending on location) at Yoakum, 17 miles downstream from Pendleton, was 669 cfs from 1935 to 1985[12]. A lower gage at Umatilla, near the mouth of the river, has a considerably smaller mean discharge, 490 cfs, because of irrigation diversion, and does not reflect natural streamflow. Butter Creek, the largest tributary in the area of the Umatilla Basin, has a mean discharge of 28 cfs at Pine City, 20 miles above its junction with the Umatilla River.

Streamflow varies considerably through the year. At Yoakum, mean flow is 1,665 cfs during April, but decreases steadily to 91 cfs in October. During the irrigation season, most streamflow in the Umatilla River and Butter Creek is diverted for irrigation use.

Much of the northern part of the basin near the Columbia River has no (or poorly developed) surface drainage because of highly permeable soil. Surface runoff has occasionally been observed from Sand Hollow. This runoff fills depressions about 2 miles south of UMDA, from which the water infiltrates into the gravels[11].

1.2.2.1.5 Ground Water Use, Artificial Recharge, and Water Balance. An estimated ground water balance (an accounting of gains to and losses from the ground water system) has not been reported for the entire Umatilla Basin. However, Miller[11] provides information that makes possible an estimate of the ground water balance of the Ordnance Critical Ground Water Area (referred to below as the Ordnance Area), a 35-square-mile area that adjoins UMDA on the east and south. The Ordnance Area contains an unusually productive unconfined aquifer that has been tapped for irrigation. Additional information that supports an estimated natural recharge rate of approximately 0.5 inch per year (in/yr) is supplied by Bauer and Vaccaro[14]. The water balance primarily reflects the alluvium, though some pumping occurs from basalt aquifers. The water balance is dominated by artificial effects, as discussed below.

The water balance for the Ordnance Area is summarized in the following list, which reflects conditions from 1978 to 1984:

- Recharge to ground water

- Precipitation/infiltration	1,000 acre-feet per year (af/yr)
- Stream seepage	Unknown
- Canal leakage	11,000 af/yr
- Inflow from west	2,000 af/yr
- Artificial recharge (mean)	5,400 af/yr

- Discharge from ground water

- Springs/seepage to Umatilla River	2,000 af/yr
- Ground water outflow	Unknown
- Direct evapotranspiration	Small
- Pumping	18,600 af/yr

Recharge to Ground Water. Ground water recharge from precipitation in the vicinity of UMDA is estimated to be approximately 0.5 in/yr or less[14]. In the area immediately to the southeast of UMDA, however, recharge rates of approximately 2 to 5 in/yr are estimated due to irrigation activities.

Seepage from the Umatilla River probably occurs when its level is high, but the rate is unknown. Leakage from canals east of UMDA is fairly accurately measured at 11,000 af/yr. Leakage from canals south of UMDA is probably much less because of less permeable soil.

An area of 29,780 irrigated acres west of the Ordnance area is irrigated by water from the Columbia River. In the past, excess irrigation water may have recharged ground water in this area at a fast enough rate to cause northeastward flow into UMDA from off post.

An artificial recharge canal 1 mile south of UMDA is operated by the County Line Water Improvement District. It consists of 2.5 miles of unlined canal, 15 feet wide, that is supplied with water from the High Line Canal, which obtains water from Butter Creek. Recharge from the canal began in 1977, with recharge of 469 acre-feet of water. Between 1978 and 1984, annual recharge ranged from 3,149 to 6,763 af/yr, with a mean of 5,358 af/yr. Ground water levels south of UMDA have increased approximately 12 feet since 1977, and at least half of this increase is attributed to the artificial recharge canal[11].

Discharge from Ground Water. Springs occur along the Umatilla River near the northeast corner of the Ordnance Area. Their discharge, though estimated, increases markedly during the irrigation season because of leakage from nearby canals.

Ground water flows out of the Ordnance Area in the subsurface, but information on gradients and flow direction is too sparse to estimate its flow rate.

Evapotranspiration directly by plants whose roots reach the saturated zone is probably slight, because in most parts of the area the depth to ground water appears to be several tens of feet.

Pumping, largely for irrigation, is the major discharger of ground water. Total pumpage (18,600 af/yr) has been relatively stable since 1971.

1.2.2.1.6 Meteorology. The following meteorological information is compiled from data from Gale Research Company and U.S. Environmental Data Service[15].

UMDA is located within the northern portion of the Columbia Basin, which enjoys a relatively mild climate. The temperature ranges from 24° to 90°F, with a mean annual temperature of 52.6°F. Normal daily average temperatures vary from 35°F in January to 70°F in July. The mild temperatures are a result of the moderating effect of the Pacific Ocean to the west.

The majority of the moisture picked up from the Pacific Ocean falls on the western slopes of the Pacific Coast Range and the Cascades as the air mass moves eastward. Precipitation in the Hermiston area is relatively low, with an annual mean of 8.87 inches. Only about 10 percent of the annual precipitation falls in summer. For the month of January, the mean total precipitation is 1.91 inches; during July, the mean total is only 0.23 inch. The area receives an average of 9.8 inches of snow annually.

Mean relative humidity varies from 80 percent in January to only 35 percent in July. The humidity tends to be approximately five percent higher in the morning throughout the

year. Consistent with the low summer humidity, 80 to 90 percent annual evaporation occurs between May and September.

1.2.2.2 Individual Site Descriptions

1.2.2.2.1 Site 7 - Aniline Pit. The Aniline Pit is located within a small fenced area in the south-central portion of the ADA area. This pit was reportedly used to dispose of aniline, a missile fuel component.

Most of the fenced area is currently vegetated with low scrub grasses, and there is a small area of bare gravel in the center. There is currently no evidence of a pit within the fenced area, although a pit was identified in aerial photographs from 1956 through 1975. As evidenced from the aerial photographs, the pit was in active use from 1958 until 1970.

The Aniline Pit covers an area of approximately 10,000 square feet. Topography is relatively flat and gently sloping to the northwest. Average elevation within the site is about 570 feet above MSL. Surface drainage is in the direction of slope, but is poorly developed.

Soils within the Aniline Pit area consist of poorly graded, fine- to medium-grained sand to approximately 4 feet. Below 4 feet, the soil becomes a well-graded sand.

1.2.2.2.2 Site 8 - Acid Pit. The Acid Pit is a small, limestone-lined, pit located immediately south of the Aniline Pit. The pit was reportedly used for the disposal of red fuming nitric acid (RFNA), a missile and rocket fuel oxidizer.

The Acid Pit was first seen in aerial photographs from 1956 and is currently in evidence. Based on the aerial photographs, the pit was most active around 1958 and activity was observed to be declining in 1965.

The Acid Pit covers about 1,600 square feet. Topography of the area is characterized by small northeast-southwest trending ridges and a gently northwest slope. The elevation of the site is approximately 570 feet above MSL. Surface drainage is in the direction of slope.

Ground water elevation at the site is approximately 465 feet and the flow direction appears to be nearly due north.

Soils at the Acid Pit were observed to be primarily fine- to medium-grained sands and gravels, becoming silty with depth.

1.2.2.2.3 Site 13 - Smoke Canister Disposal Area. The Smoke Canister Disposal Area is located in the west-central portion of the ADA. This area was used to dispose of burned debris from the UMDA canister burning operations that took place at Site 39, QA Function Range.

The western and central portions of this area consist of a long, narrow, and discontinuous mound of soil (500 feet long and 30 to 40 feet wide) containing abundant smoke canister debris and other metal debris. The eastern one-quarter to one-third of the site consists of a shallow grass-covered trench with no metal debris observed at the surface. The Smoke Canister Disposal Area was visible in a 1950 aerial photograph and was apparently active until sometime between 1965 and 1970. Grading has occurred at the site.

The Smoke Canister Disposal Area covers about 2.5 acres. Topography of the area is relatively flat and gently sloping to the northwest with the most obvious features being the long, discontinuous mound and shallow depression making up the site itself. The elevation of the site is approximately 520 feet above MSL. Surface drainage is radially away from the mounded area.

Ground water elevation at the site is approximately 440 feet and the flow direction is apparently north-northeast.

Soils at this Area are predominantly fine-grained sand, that grades to silty sand at depths of approximately 70 feet.

1.2.2.2.4 Site 14 - Flare and Fuse Disposal Area/Bird Cage Burn Area. Site 14 is located in the west-central portion of the ADA. This site was used to dispose of burned residue from the UMDA flare and fuse burning operation. Reportedly, pyrotechnics were burned at this site in a separate area referred to as the "bird cage."

This area is currently characterized by a 30- by 50- by 5-foot high mound of soil with a few metal fragments visible on the mound surface and in the general vicinity. The "bird cage" is first visible in aerial photographs taken in 1956. The mound of soil is visible in 1968 photographs. Changes in the area were observed in aerial photographs from 1956 to 1980.

Site 14 covers approximately 30,000 square feet. Topography of the site is relatively flat with a gentle northwest slope. The elevation of the site is approximately 525 feet above MSL. Surface drainage at the site is radially away from the mound.

Ground water elevation in the vicinity of Site 14 was estimated at about 465 feet. Indications are that the main ground water flow direction within the site is north-northeast.

Soils at Site 14 are predominantly fine- to medium-grained sand that grades to silty-sand at a depth of approximately 55 feet.

1.2.2.2.5 Site 15 - TNT Sludge Burial and Burn Area. This area is located in the north-central portion of the ADA. Previous investigations at this site concluded that

TNT-containing sludges from the Explosives Washout Plant (Building 489) may have been dumped and burned here. Former installation personnel, however, indicated that paint sludges, shot blast wastes, and deactivation furnace ash and residue were more likely to have been disposed of or burned at this site.

There are at least two mounds of reddish-brown dried sludge material at this site in addition to a variety of burned metal and wood debris. Vegetation is sparse and appears to be stressed. Based on aerial photographs, activities at Site 15 took place in 1950 (or before). Changes in the site were observed through a series of aerial photographs dating from 1950 to 1988. Over the years, the site has apparently been subjected to occasional (and sometimes extensive) grading.

The total area of Site 15 is approximately 4.4 acres. The site is relatively flat but with a gentle slope to the north. The elevation of the site is approximately 490 feet above MSL. Surface drainage is to the north, in the direction of topographic slope.

Ground water beneath Site 15 is estimated at a depth of about 75 feet. Ground water flow was determined to be in a north-northeast direction in the vicinity of the site.

Soils at Site 15 are a fine- to medium-grained, well-graded sand with some silt. The silt concentration becomes greater with depth.

1.2.2.2.6 Site 16 - Open Detonation Pits. The Open Detonation Pits are located in the central portion of the ADA. These pits have been, and are currently being used for the detonation of various conventional munitions. UMDA currently conducts detonation operations at this site under an Air Contaminant Discharge Permit from the ODEQ[16]. These operations will cease in September 1994 at which time they will be closed under the conditions of the permit. Possible soil contamination at this site will be addressed as part of the ADA operable unit in this Feasibility Study.

There are several rows of pits, with about 8 to 12 pits (spaced approximately 100 feet apart) per row. The pits are typically 15 feet wide and approximately 5 to 8 feet deep. Very little vegetation exists in the active part of this site. Sparse and stressed vegetation and abundant debris were observed at various locations. Aerial photographs dating from 1950 give evidence of activities at the site. Throughout the course of site activities, aerial photographs give evidence that more than 40 pits existed in the site area. Some of the pits had been graded over.

Site 16 covers approximately 62 acres. Topography of the area is relatively flat and consists of a number of low-lying ridges extending northeast-southwest. The elevation of the site is approximately 560 above MSL. Surface drainage is to the north-northwest, in the direction of topographic slope.

Ground water beneath Site 16 is estimated to be at a depth of approximately 95 feet. There is an overall northwestward ground water flow direction across the site.

Soils at Site 16 are fine- to medium-grained, moderately graded sand becoming siltier with depth. In some pits, soil samples indicated the presence of an ash material and cemented sands.

1.2.2.2.7 Site 17 - Aboveground Open Detonation (OD) Area. The OD Area is located in the central portion of the ADA. The Area was used for the detonation of decontaminated M55 rockets and M23 land mines.

In OD operations at Site 17, munitions were placed in a horizontal steel tube running through the center of a 5- by 5- by 4-foot high, gravel-filled metal bin for detonation. Abundant metal fragments are present on the soil and a mound of fine-grained soil, possibly containing some ash material, is present. The site was apparent only on aerial photographs taken in 1980 and 1988.

Site 17 is approximately 2.3 acres. The topography of the area is relatively flat, but the site is bordered by a small ridge immediately to the north. Average elevation of the site is 515 feet above MSL. Surface drainage is poorly developed, but runoff from the ridge to the north may cause ponding in the vicinity of the site during periods of heavy rainfall.

The depth to ground water at Site 17 is estimated at approximately 72 feet. The probable direction of ground water flow beneath the site is to the north-northeast.

Surface soils encountered at Site 17 included poorly graded, fine- to medium-grained sand and well-graded, coarse-grained sand.

1.2.2.2.8 Site 18 - Dunnage Pits. The Dunnage Pits are located in the north-central portion of the ADA. The two currently visible pit areas are separated by a gravel road with the larger pit on the west side of the road.

The Pits were reportedly used to dispose of and burn dunnage and possibly liquid wastes such as waste solvents, oils, paint strippers, and sludges from the Explosives Washout Plant operations.

Aerial photographs indicate that a least six dunnage pits once existed in the area east of the current pits. When pits were full, they were apparently graded over and new pits were dug. The pits were first apparent in 1956 photographs. The two existing pits were first noted in the 1988 photographs.

The entire Site 18 area covers approximately 6.5 acres. The site is relatively flat, with a gentle slope to the north. The elevation of the site is approximately 495 feet above MSL. Surface drainage is to the north, in the direction of topographic slope.

Ground water depth is estimated at approximately 79 feet below the surface. An overall northwestward ground water flow direction across the site is indicated.

Soil immediately below Site 18 is fine- to medium-grained, poorly to moderately well-graded sand becoming siltier with depth. In sample test pits located in Dunnage Pits, soil was discolored and contained ash and charcoal material.

1.2.2.2.9 Site 19 - Open Burning (OB) Trenches/Pads. The OB Trenches/Pads are located in the north-central portion of the ADA. The trenches were reportedly used to burn a variety of debris and waste, including ordnance waste. Former UMDA personnel indicate that explosive sludges from Explosives Washout Plant operations were burned in the northernmost trenches and that pesticides and furnace ash may also have been burned in this area.

The site consists of two adjacent parts: a row of approximately 10 former burn trenches; and a burn field area to the north and east of the burn trenches. Pits and trenches at the site have been apparent in aerial photographs dating from 1950. The site has been subjected to periodic grading.

Site 19 covers approximately 50 acres. It is relatively flat, with a gentle topographic slope to the north. The elevation of the site ranges from approximately 460 feet above MSL in the north to 530 feet above MSL in the south. Surface drainage is poorly developed, but is expected to be to the north, in the direction of topographic slope.

Depth to ground water at Site 19 ranges from 67 to 95.5 feet, with an estimated average of approximately 81 feet. Ground water flow direction varies somewhat across the site. A northwestward flow was detected beneath the eastern part of the site. Ground water flows nearly due north beneath the western part of the site.

Site 19 is immediately underlain by fine- to medium-grained, poorly to well-graded sand with minor gravel. The gravel does not appear to be native to the ADA. Several of the soil samples in the trenches indicated the presence of ash or a cemented white material.

1.2.2.2.10 Site 21 - Missile Fuel Storage Areas. The Missile Fuel Storage Area is located in the south-central portion of the ADA. The area contains sheds that were used to store missile fuel components.

Three sheds were first apparent in aerial photographs taken in 1956. In 1965 photographs, a fourth shed was observed. In 1968, graded areas on the south and east edges of the site were observed. In 1974 photographs, one of the sheds was gone. Changes to the site were observed in aerial photographs from 1956 to 1980.

Site 21 covers approximately 40 acres. The site is characterized by gently rolling topography, with an overall slope to the north. A typical site elevation is 574 feet above MSL. Surface drainage is poorly developed, but is generally to the north.

Ground water was encountered during well installation at a depth of 76 feet. Water level data from wells adjacent to the site indicate that the primary ground water flow direction under the Missile Fuel Storage Area is nearly due north.

1.2.2.2.2.11 Site 31 - Pesticide Pits. The Pesticide Pits are located in the south-central portion of the ADA. Some former UMDA personnel indicated that these pits were used to burn or dispose of pesticide solutions. Other personnel contended that pesticide solutions were never disposed of at UMDA, but were shipped off site to other Army depots for disposal.

Currently, 10 open pits are located in an east-west trending row in the site area. Every other pit is offset along this row. The open pits are approximately 15 feet in diameter and are partially filled with debris to a depth of about three feet below grade. In addition, at least two former pits are located in line with, and east of, the 10 open pits. The site was first apparent in aerial photographs dating from 1950. Pits were first observed in 1958 photographs. Based on aerial photographs, activities at the site were conducted from the 1950s to the 1980s. Grading at various portions of the site took place throughout those years.

The Pesticide Pits cover an area of approximately 36 acres. The site is relatively flat with a gentle topographic slope to the north. The elevation of the site is approximately 570 feet above MSL. Surface drainage is to the north, in the direction of topographic slope.

Depth to ground water is estimated at approximately 86 feet. Overall ground water flow direction is indicated to be to the north.

Soil at the site consists of fine- to medium-grained, poorly to well-graded sand with minor surface gravels. With depth, the sand gradually fines to silt and finer sands near the water table.

1.2.2.2.12 Site 32 - Open Burning Trays. Two areas of Open Burning Trays are located in the central portion of the ADA: one area is in the north area, the other is in the south area. The steel trays with aluminum covers are used to burn explosives and propellant from disassembled small munitions. UMDA conducts burning operations at this site under an Air Contaminant Discharge Permit from the ODEQ[16]. These trays will cease operation in September 1994 at which time they will be closed under the conditions of the permit. Possible soil contamination at this site will be addressed as part of the ADA operable unit in this Feasibility Study.

The southern tray site was in evidence in aerial photographs taken in 1950. The northern site was visible in 1951 photographs. Various levels of activity existed at the northern and southern sites from 1950 to the present.

Each area of Site 32 covers approximately one acre. Topography within both areas is relatively flat. However, regional topographic slope is to the north. The elevation of the

northern burn tray is approximately 508 above MSL, while the elevation of the southern burn tray is approximately 530 feet above MSL. Surface drainage in both areas is poorly developed, with precipitation expected to infiltrate rapidly into the coarse-grained near-surface soils.

Depth to ground water at the northern tray site is approximately 75 feet. Ground water at the southern tray site is approximately 85 feet below the surface. The primary direction of ground water flow at both Site 32 areas is expected to be due north.

Surface soils collected at both Site 32 areas consisted of poorly graded, medium- to fine-grained sand. This soil was intermixed with some non-native gravels from the gravel pad.

1.2.2.2.13 Site 38 - Pit Field Area. The Pit Field Area is located in the central portion of the ADA. It is believed that these pits may have been used to explode and dispose of old or faulty ordnance.

Aerial photographs and on-site observations reveal the existence of several rows of pits approximately 8 to 10 feet in diameter and about one to two feet deep. Nearly 100 pits were identified during on-site inspections. The pits are visible in aerial photographs as early as 1950. Later photographs indicate that the pits were periodically used until 1968. There was apparently no grading of the area during this period.

Site 38 covers approximately 52 acres. The site is characterized by small northeast-southwest trending ridges, with an overall topographic slope to the north. The elevation of the site ranges from approximately 520 feet above MSL in the north to approximately 545 fee above MSL in the south. Surface drainage is poorly developed, but is generally to the north.

Based on available data, ground water beneath Site 38 is at an average depth of 76 feet. An overall northeastward ground water flow direction is assumed at the site.

Site 38 is immediately underlain by fine- to medium-grained, poorly graded sand and silty sand, with some cementation or compaction at various depths within the top 10 feet.

1.2.2.2.14 Site 41 - GB/VX Decontamination Solution Burial Areas. Site 41 is the location of a suspected burial area for solutions used to decontaminate munitions containing GB or VX. The site is located at the northwestern part of the ADA.

The site was first observed in aerial photographs taken in 1956. Initially, a trench and a pile of soil were observed. The pile of soil was no longer visible in 1958 photographs. In 1970, the trench appeared to be abandoned and a new pit was noted. The pit was observed to be active in 1972. No significant level of activity was noted from 1974 to 1988. In 1988 photographs, it was observed that both the trench and the pit had been covered with soil.

Site 41 consists of a trench and a pit. The topography in the general area is relatively flat, but with a gentle slope to the northwest. The surface elevation at the site is approximately 460 feet above MSL. Surface drainage is to the northwest.

Ground water beneath Site 41 is estimated to be at a depth of approximately 64 feet. Ground water flow direction is to the north.

Soil at the site is characterized by loose, poorly graded sand to a depth of 10 feet. The soil gradually fines with depth to a silt before bedrock is encountered at a depth of approximately 60 feet.

1.2.2.2.15 Site 55 - Trench/Burn Field. Site 55 is located in the northcentral portion of the ADA. It consists of several rows of burn trenches; however, interviews with current or former UMDA personnel did not reveal any specific operations that took place at the site.

The burn trenches (consisting of three northwest-southeast trending rows of trenches) were observed to be quite active in 1950 aerial photographs. These trenches appeared to have been abandoned by 1956. In the 1956 photographs, the TNT Sludge Burial and Burn Area (Site 15) had been constructed over the eastern portion of Site 55.

Site 55 covers an area of approximately 9 acres. Topography within the area slopes to the northwest, with an average elevation of about 490 feet above MSL. Surface drainage is poorly developed, but is generally in the direction of slope.

It is estimated that depth to ground water beneath this site is approximately 70 to 80 feet. Ground water flow direction is expected to be northeast.

The surface soil encountered at the site consisted of poorly graded, fine- to medium-grained sand.

1.2.2.2.16 Site 56 - Munitions Crate Burn Area. Site 56 is located in the northcentral portion of the ADA. This area was reportedly used to burn empty wooden crates that were used to hold munitions.

Aerial photographs indicate that Site 56 was active prior to 1950 through 1965. In 1950 photographs, the area consisted of a dark-toned circular area with a diameter of approximately 80 feet. Some grading was apparently performed at the site between 1956 and 1958. The site was apparently abandoned by 1956.

The Munitions Crate Burn Area covers approximately 2 acres. Topography of the area is relatively flat and gently sloping to the northwest. Average elevation of the site is about 520 feet above MSL. Surface drainage is poorly developed but expected to be to the northwest.

Depth to ground water at Site 56 is expected to be 80 to 90 feet. A northwestward ground water flow direction is assumed.

Soils near the surface (to 3.5 feet) consisted of a well-graded, fine- to medium-grained sand. Soil from 3.5 to 5.5 feet deep samples indicated a poorly graded, fine- to medium-grained sand.

1.2.2.2.17 Site 57 - Former Pit Area Locations. Site 57 consists of three areas designated as Locations I, II, and II located in the northcentral, central, and southcentral portions (respectively) of the ADA. Although specific uses of the sites were not revealed in interviews with former UMDA personnel, it is assumed that operations involving the detonation and/or burning of munitions were conducted consistent in nature to those conducted elsewhere in the ADA.

All of the areas were active or appeared to be disturbed in aerial photographs prior to 1950. No activities at Location I were observed in subsequent photographs and a recent on-site inspection revealed that these pits are no longer apparent. Changes at Location II were minimal in photographs from 1950 to 1988; however, the pits are still apparent. Some activities were observed at Location III in 1951 and 1956 photographs. No changes were observed at Location III from 1956 to the present, although the pits are still apparent.

Location I covers approximately 18 acres. The topography at this location is relatively flat with a gentle slope to the northwest. Elevations range from approximately 470 to 500 feet above MSL. Surface drainage is poorly developed, but is generally to the north. Ground water depth is approximately 72 feet and flows nearly due north.

Location II covers roughly 20 acres. The site is situated in a valley between two northeast-southwest trending ridges. Topography is relatively flat, with the exception of the long mound created by Site 13 that overlays the area. Elevations average about 518 feet above MSL. Surface drainage is poorly developed, but is generally toward the valley from either ridge and radially from the mound formed by Site 13. Depth to ground water is estimated at 65 to 90 feet. Ground water flow direction is slightly northeast.

Location III is approximately 60 acres in area. Topography consists of a series of northwest-southeast trending low-lying ridges and an overall gentle northwest slope. The average elevation in this area is approximately 570 feet above MSL. Surface drainage is poorly developed, but is generally to the northwest. Depth to ground water is estimated at approximately 82 feet. Ground water flow direction is nearly due north.

Soils underlying Locations I and II consist of fine - to medium-grained, poorly to well-graded sand. Location III is immediately underlain by fine-grained, silty sand.

1.2.2.2.18 Site 58 - Borrow/Burn/Disposal Area. Site 58 is located in the northeast corner of the ADA. The specific activities that took place at this site are unknown; however, it is assumed that ammunition demolition or disposal activities similar to those conducted elsewhere took place.

The site appeared as a bare, light-toned area in a 1950 aerial photograph. Photographs from the mid-1950s indicate that burning activities may have taken place at the site. Limited activities at the site were apparent in photographs through 1968. By 1970, site definition was minimal. Current visual inspections revealed only a light-toned grass and a few charred pieces of wood.

Site 58 covers approximately 4 acres. Topography consists of gently rolling hills, with a regional slope to the northwest. Surface elevation of the site is approximately 460 feet above MSL. Surface drainage is poorly developed, but is expected to be toward the northwest.

Depth to ground water at Site 58 is estimated to be about 70 feet. A northwestward ground water flow direction is assumed.

Soils at the site consist of a moderately well-graded, fine- to medium-grained sand.

1.2.2.2.19 Site 59 - GB/VX Decontamination Solution Disposal Areas. This site is located in the central portion of the ADA. Reportedly, GB/VX decontamination solutions were disposed of on the bare soil in site areas in the early 1960s.

Bare soil areas were visible in aerial photographs from 1950. In 1958 photographs, the northern part of the site was shown to contain a spot that appeared to be wet or stained by a liquid. Photographs from 1958 to 1980 indicate limited activities at the site. A 1988 photograph shows a bare area of ground in the southern part of the site. Based on the photographic observations, it was concluded that the two identified areas were the most likely disposal locations.

Site 58 consists of two pits. The site is relatively flat, but with a gentle slope to the northwest. The surface elevation at the site is approximately 560 feet above MSL. Surface drainage is to the northwest, in the direction of slope.

Depth to ground water at Site 59 is estimated to be at an average depth of approximately 105 feet. Overall ground water flow direction is apparently to the north-northwest.

Surface soil at the site consists of fine- to medium-grained, well-graded sand. Subsurface soil is similarly grained, but poorly graded.

1.2.2.2.20 Site 60 - Active Firing Range. The Active Firing Range is located near the southwest corner of the ADA. The site includes an active rifle and machine gun and

grenade range in the western portion and an active pistol range in the eastern portion. The firing range has been in use by the National Guard since the early 1980s. There are no man-made impact areas behind the targets in either shooting location.

A review of aerial photographs revealed no significant information regarding this site. An on-site visual inspection revealed the presence of a significant number of bullets and blue plastic grenade fragments.

Site 60 covers approximately 18 acres. A small northwest-trending ridge is present at the center of the site. Typical site elevations are 570 to 575 feet above MSL. Surface drainage is poorly developed, but is in the direction of topographic slope. The firing range is sparsely vegetated, which increases the extent of wind erosion at this site.

The depth to ground water is estimated at about 50 feet. It is expected that the ground water flow direction is probably north or slightly northeast, consistent with overall ADA ground water flow.

Surface soils consist of poorly graded, medium- to fine-grained sand.

1.2.3 Nature and Extent of Contamination

The following discussion provides a brief description of the nature and extent of contaminants detected at the ADA sites. This summary is based on data and information developed in the RI (and supplemented by the RA) and describes the occurrence of contaminants of concern. A more detailed description and summary of contaminants of concern in soil and ground water is provided in Section 1.2.5.1, Selection of Contaminants of Concern. The development of affected (contaminated) areas and soil volumes is presented in Section 2.3.2, Estimated Areas and Volumes of Contaminated Media Requiring Remediation. It should be noted that since the completion of the RI and RA, additional soil sampling and analyses have been performed at ADA Sites 15, 17, 18, and 19. The effect of these additional soil characterizations on the development of contaminated soil areas and volumes is provided in Appendix B of this report.

At each site, it was determined that the primary route of migration of contaminants in soil was through windblown dust. Based on data developed in the RI, it appears unlikely that soil contamination at the ADA sites has impacted ground water quality underneath the ADA.

1.2.3.1 Site 7 - Aniline Pit. There was no detectable organic or inorganic contamination in soil at this site. Ground water was not characterized at this site.

1.2.3.2 Site 8 - Acid Pit. Soil was found to contain metals to 10 feet at this site. Contaminants detected in ground water included: metals, explosives, nitrite/nitrate, and volatile organics.

1.2.3.3 Site 13 - Smoke Canister Disposal Area. Soil at the site was found to contain metals and explosives to 10 feet. Metals were detected in ground water.

1.2.3.4 Site 14 - Flare and Fuse Disposal Area/Bird Cage Area. Soil was found to contain metals to 2 feet and metals and nitrate/nitrite to 10 feet. Metals were detected in ground water.

1.2.3.5 Site 15 - TNT Sludge Burial and Burn Area. Soil was found to contain metals, explosives, and nitrate/nitrite to 2 feet and 10 feet. Metals were detected in ground water.

1.2.3.6 Site 16 - Open Detonation Pits. Soil was found to contain metals, cyanide, explosives, and nitrate/nitrite to two feet and 10 feet. Metals were detected in ground water.

1.2.3.7 Site 17 - Aboveground Open Detonation Area. Metals and explosives were found in surface soils. Ground water was not characterized at this site.

1.2.3.8 Site 18 - Dunnage Pits. Soil was found to contain metals to 2 feet and metals, semivolatile organics, and pesticides to 10 feet. Metals were detected in ground water.

1.2.3.9 Site 19 - Open Burning Trenches/Pads. Soil was found to contain metals, explosives, and nitrite/nitrate to 2 feet and metals, explosives, nitrite/nitrate, and volatile organics to 10 feet. Metals and explosives were detected in ground water.

1.2.3.10 Site 21 - Missile Fuel Storage Areas. No contaminants of concern were detected in soil at this site. Ground water was not characterized at this site.

1.2.3.11 Site 31 - Pesticide Pits. Soil was found to contain metals, explosives, nitrite/nitrate, semivolatile organics, and pesticides to 2 feet and to 10 feet. Contaminants detected in ground water included: metals, explosives, nitrite/nitrate, and volatile organics.

1.2.3.12 Site 32 - Open Burning Trays. Soil at locations I and II were found to contain metals, explosives, and nitrite/nitrate to 2 feet. Ground water was not characterized at this site.

1.2.3.13 Site 38 - Pit Field Area. Soil was found to contain metals and explosives to 10 feet. Metals were detected in ground water.

1.2.3.14 Site 41 - GB/VX Decontamination Solution Burial Areas. Soil was found to contain metals to 10 feet. Metals were detected in ground water.

1.2.3.15 Site 55 - Trench/Burn Field. Soil was found to contain explosives to 10 feet. Metals were detected in ground water.

1.2.3.16 Site 56 - Munitions Crate Burn Area. Soil was found to contain metals to two feet and to 10 feet. Ground water was not characterized at this site.

1.2.3.17 Site 57 - Former Pit Area Locations.

Location I. Soil was found to contain metals to 10 feet. Metals were detected in ground water.

Location II. Soil was found to contain metals to 10 feet. Metals were detected in ground water.

Location III. Soil was found to contain metals to 2 feet and metals and explosives to 10 feet. Metals were detected in ground water.

1.2.3.18 Site 58 - Borrow/Burn/Disposal Area. No contaminants were detected in soil at this site. Ground water was not characterized at this site.

1.2.3.19 Site 59 - GB/VX Decontamination Solution Disposal Areas
No contaminants were detected in soil or ground water at this site.

1.2.3.20 Site 60 - Active Firing Range. Soil samples were taken at the target areas and in an area of abundant bullets and grenade fragments. Soil was found to contain metals to 2 feet. Ground water was not characterized at this site.

1.2.4 Contaminant Fate and Transport

The exposure to humans and the environment imposed by the contaminants of concern identified at UMDA is influenced by a number of factors. These factors include the interrelated characteristics of the contaminants such as physical and chemical properties and environmental fate and transport parameters. Fate and transport profiles for each of the contaminants of concern at UMDA are presented in Appendix C of the RA[4]. Physical and chemical characteristics and environmental fate parameters for organic and inorganic contaminants of concern at UMDA are summarized in Tables A-1 and A-2 in Appendix A of this FS. Note that Appendix A has been extracted from the RA; full reference citations are provided in the RA[4].

The primary factors that affect the fate and transport of contaminants of concern in soil at the ADA include: photolysis, sorption (absorption and adsorption) to soil; and bioaccumulation. To a more limited extent, biotransformation and biodegradation may impact the fate and transport of the organic contaminants of concern. Mobility of the contaminants through soil to ground water is not a particular concern at the ADA due to the relative immobility of the contaminants of concern as well as the depth to ground water (in excess of 50 feet).

In general, the metals found at the ADA are relatively immobile in soil. This immobility is affected by the insolubility of the metals in water as well as the sorption of some metals to soil particles. The metals are generally present in nonvolatile forms and are nondegradable, both characteristics that will limit the potential for natural restoration of the soil. Many of the metals found at the ADA will bioaccumulate and therefore impact specific human and environmental exposure routes.

The fate and transport of explosive contaminants of concern at the ADA are primarily affected by photolysis and sorption. Although the explosives are generally resistant to biodegradation, degradation has been observed under optimum conditions. In general, the explosive contaminants are nonvolatile and are insoluble in water.

Sorption of pesticide contaminants of concern to soil is an important factor in the environmental fate and transport of these compounds. In dry soils, volatility of the pesticides is not a significant factor in their transport. The pesticides are relatively insoluble in water.

1.2.5 Human Health Baseline Risk Assessment

This section of the FS summarizes the results of the Human Health Baseline Risk Assessment (RA) of the ADA[4]. For a detailed presentation of the results, and a thorough discussion of methodology employed, refer to the RA.

1.2.5.1 Selection of Contaminants of Concern. The data used in the development of the RA are from the Weston[17] and/or Dames and Moore (1990-1992) remedial investigations. These particular data were selected because they better represent current site conditions and because sample collection and analysis were conducted using USATHAMA protocols. The potential contaminants of concern from those investigations were those that met one or more of the following criteria:

- Positive detection in at least one sample in at least one medium
- Significant elevation above method blanks (5-10 times the method blank concentration depending on the compound)
- Inorganic compounds present at concentrations above the maximum background sample concentration
- Tentatively Identified Compounds (TICs) if known to be site related
- Identified as transformation products of other contaminants of concern

Contaminants identified in ground water and soil based on the above criteria for the ADA are summarized in Table 1-1 and Table 1-2, respectively. For reference, background concentrations of the contaminants are included (if available or appropriate) in these tables. In addition, for future reference, Table 1-2 provides risk-based concentrations of contaminants that represent an excess cancer risk of 1×10^{-6} or a hazard quotient of 1. These data will be discussed in Section 1.2.5.5, Risk Based Remedial Action Criteria, and are presented here for reference only.

Table 1-1. Summary of Contaminants of Concern in Ground Water

Site	Contaminant of Concern	95% UCL Concentration ug/l	Frequency of Detection	Background Concentration ug/l (a)
8 and 31	Antimony	2.75	3 of 9	1
	Arsenic	27	10 of 10	1
	Barium	82.8	8 of 8	59
	Copper	4.78	2 of 10	1
	Vanadium	96.2	8 of 8	NSA
	Zinc	389	1 of 9	40
	RDX	0.76	1 of 10	NSA
	Benzene	0.417	1 of 10	NSA
	Nitrite/nitrate	18996	8 of 10	54000
13 and 57II	Antimony	5.71	1 of 4	1
	Arsenic	30.5	4 of 4	1
	Barium	118	4 of 4	59
	Selenium	3.99	1 of 4	1
	Vanadium	36.6	4 of 4	NSA
14 and 38	Antimony	2.72	1 of 4	1
	Arsenic	32.8	4 of 4	1
	Barium	104	4 of 4	59
	Chromium	13.8	4 of 4	1
	Selenium	11.2	4 of 4	1
	Vanadium	43.8	4 of 4	NSA
15 and 55	Antimony	3.13	1 of 2	1
	Arsenic	17	2 of 2	1
	Barium	104	2 of 2	59
	Manganese	238	2 of 2	140
	Zinc	71.2	1 of 2	40
16	Arsenic	26.8	6 of 6	1
	Barium	71.5	6 of 6	59
	Selenium	4	6 of 6	1
	Vanadium	141	6 of 6	NSA
18	Arsenic	40	2 of 2	1
	Barium	147	2 of 2	59
	Manganese	369	2 of 2	140
	Vanadium	19.1	2 of 2	NSA

Table 1-1. Summary of Contaminants of Concern in Ground Water (continued)

Site	Contaminant of Concern	95% UCL Concentration ug/l	Frequency of Detection	Background Concentration ug/l (a)
19	Antimony	18.4	2 of 7	1
	Arsenic	18.2	7 of 7	1
	Beryllium	0.5	1 of 7	NSA
	Copper	3.32	1 of 7	1
	Lead	9.53	1 of 7	5
	Nickel	17.7	1 of 7	NSA
	Selenium	29.8	2 of 7	1
	Vanadium	89.5	6 of 6	NSA
	1,3- DNB	0.484	1 of 6	NSA
41	Antimony	2.34	1 of 7	1
	Arsenic	26.5	7 of 7	1
	Barium	74.2	6 of 6	59
	Beryllium	0.5	1 of 7	NSA
	Chromium	6.09	1 of 7	1
	Copper	6.36	2 of 7	1
	Lead	9.88	3 of 7	5
	Nickel	17.7	1 of 7	NSA
	Vanadium	63	6 of 6	NSA
	Zinc	30	2 of 7	40
57I	Antimony	5.07	2 of 4	1
	Arsenic	30.8	4 of 4	1
	Barium	104	4 of 4	59
	Chromium	13.2	2 of 4	1
	Copper	8.78	1 of 4	1
	Manganese	189	4 of 4	140
	Vanadium	37.1	2 of 4	NSA
	Zinc	40.7	1 of 4	40
57III	Antimony	3.21	3 of 6	1
	Arsenic	27.4	6 of 6	1
	Barium	87.6	6 of 6	59
	Mercury	0.449	1 of 6	0.4
	Vanadium	56.8	6 of 6	NSA
59	None			

UCL - Upper Confidence Limit
NSA - No Standard Available
(a) - Background concentration as established in RI

Note: Ground water was not characterized at Sites 7, 17, 21, 32, 56, 58, and 60.

Table 1-2. Summary of Contaminants of Concern in Soil

Site	Contaminant of Concern	95% UCL Concentration to 2-foot depth ug/g	Frequency of Detection	95% UCL Concentration to 10-foot depth ug/g	Frequency of Detection	Background Concentration ug/g (a)	Risk-Based Concentration ug/g (b)
7	None	NDB		NDB			
8	Lead	NA		18.7	4 of 4	500	500 (c)
	Nickel	NA		15.2	4 of 4	12.6	470
	Zinc	NA		3796	2 of 4	94	54800
13	Antimony	16.1	1 of 5	6.08	1 of 15	3.8	110
	Arsenic	14.4	5 of 5	7.85	15 of 15	5.24	0.363
	Iron	103653	5 of 5	49282	15 of 15	26233	Not applicable (c)
	Lead	321	5 of 5	98.8	15 of 15	500	500
	Manganese	774	5 of 5	659	15 of 15	874	15200
	Mercury	0.512	4 of 5	0.201	4 of 15	0.056	81.9
	Nickel	85.7	2 of 5	40	4 of 15	12.6	470
	Silver	6.05	5 of 5	1.93	7 of 15	0.038	1370
	Zinc	26568	5 of 5	9611	15 of 15	94	54800
	2,6-DNT	0.831	1 of 5	0.429	1 of 15	NSA	0.0723
14	Barium	311	1 of 2	289	10 of 12	233	13700
	Chromium (d)	188	1 of 2	48.7	1 of 12	32.7	19
	Lead	330	2 of 2	86.2	12 of 12	500	500
	Potassium	2320	2 of 2	1867	12 of 12	2179	Not applicable (c)
	Silver	0.062	1 of 2	0.03	3 of 12	0.038	1370
	Zinc	1710	2 of 2	459	10 of 12	94	54800
15	Antimony	3396	3 of 4	832	4 of 14	3.8	110
	Arsenic	20	4 of 4	10.6	14 of 14	5.24	0.363
	Barium	7781	2 of 4	2118	11 of 14	233	13700
	Beryllium	12.9	2 of 4	4.98	3 of 14	1.86	0.148
	Cadmium	2935	2 of 4	1057	4 of 14	3.05	127
	Chromium (d)	7160	3 of 4	1937	6 of 14	32.7	19
	Cobalt	239	2 of 4	80.2	4 of 14	15	2.74
	Copper	3120	3 of 4	936	4 of 14	1300	10100
	Iron	130000	4 of 4	63112	14 of 14	26233	Not applicable (c)
	Lead	695	4 of 4	220	14 of 14	500	500
	Magnesium	16199	4 of 4	10369	14 of 14	8585	Not applicable (c)
	Manganese	1881	4 of 4	1070	14 of 14	874	15200
	Mercury	0.201	1 of 4	0.071	2 of 14	0.056	81.9
	Nickel	306	3 of 4	103	4 of 14	12.6	470
	Potassium	3740	4 of 4	2112	14 of 14	2179	Not applicable (c)
	Selenium	5.57	2 of 4	1.165	3 of 14	0.25	1370
	Silver	2.17	3 of 4	0.772	6 of 14	0.038	1370
	Sodium	2094	4 of 4	1153	14 of 14	978	Not applicable (c)
	Thallium	708	2 of 4	250	3 of 14	31.3	21.9
	Zinc	22813	4 of 4	7229	14 of 14	94	54800
	1,3,5-TNB	1.42	1 of 4	0.549	2 of 14	NSA	1.05
	2,4,6-TNT	176	1 of 4	48.6	2 of 14	NSA	1.64
	RDX	126	2 of 4	34.8	8 of 14	NSA	5.81
	Nitrate/Nitrite	81	2 of 2	26.9	5 of 10	9.1	438000

Table 1-2. Summary of Contaminants of Concern in Soil (continued)

Site	Contaminant of Concern	95% UCL Concentration to 2-foot depth ug/g	Frequency of Detection	95% UCL Concentration to 10-foot depth ug/g	Frequency of Detection	Background Concentration ug/g (a)	Risk-Based Concentration ug/g (b)
16	Arsenic			8.59	45 of 45	5.24	0.363
	Barium	427	5 of 5	257	44 of 45	233	13700
	Cadmium	3.31	1 of 5	1.69	1 of 45	3.05	127
	Cobalt	19	1 of 5	8.58	1 of 45	15	2.74
	Copper	118	2 of 5	102	45 of 45	1300	10100
	Silver	1.49	4 of 5	0.274	26 of 45	0.038	1370
	Zinc	NDB		542	45 of 45	94	54800
	Cyanide	1.14	1 of 5	0.612	4 of 45	0.92	5480
	1,3,5-TNB	NA		0.935	1 of 45	NSA	1.05
	2,4,6-TNT	1.07	3 of 5	6.81	6 of 45	NSA	1.64
	2,4-DNT	NA		0.232	1 of 45	NSA	0.0723
	RDX	1.32	2 of 5	0.949	8 of 45	NSA	5.81
17	Antimony	85	2 of 4	NA		3.8	110
	Beryllium	3	1 of 4	NA		1.86	0.148
	Cadmium	5.25	1 of 4	NA		3.05	127
	Cobalt	23.7	1 of 4	NA		15	2.74
	Copper	299	1 of 4	NA		1300	10100
	Iron	69158	4 of 4	NA		26233	Not applicable (c)
	Lead	1460	4 of 4	NA		500	500
	Nickel	27	1 of 4	NA		12.6	470
	Silver	0.138	3 of 4	NA		0.038	1370
	Sodium	948	4 of 4	NA		978	Not applicable (c)
	Zinc	118	4 of 4	NA		94	54800
	2,4,6-TNT	3.01	1 of 4	NA		NSA	1.64
	RDX	12	3 of 4	NA		NSA	5.81
18	Aluminum	29945	4 of 4	14059	28 of 28	8604	794000
	Arsenic	6.19	4 of 4	10.5	28 of 28	5.24	0.363
	Barium	462	4 of 4	1526	28 of 28	233	13700
	Beryllium	NA		2.34	3 of 28	1.86	0.148
	Cadmium	NA		3.95	4 of 28	3.05	127
	Chromium (d)	80.6	1 of 4	22.7	6 of 28	32.7	19
	Copper	100	1 of 4	741	7 of 28	1300	10100
	Iron	NDB		33861	28 of 28	26233	Not applicable (c)
	Lead	273	4 of 4	266	28 of 30	500	500
	Manganese	1620	4 of 4	782	28 of 28	874	15200
	Nickel	389	1 of 4	63.5	7 of 28	12.6	470
	Silver	1.68	2 of 4	0.637	17 of 28	0.038	1370
	Sodium	3073	4 of 4	1544	28 of 28	978	Not applicable (c)
	Dieldrin	NA		0.005	1 of 28	NSA	0.0399
	DDE	NA		0.006	3 of 28	NSA	1.88
	DDT	NA		0.01	5 of 28	NSA	1.88

Table 1-2. Summary of Contaminants of Concern in Soil (continued)

Site	Contaminant of Concern	95% UCL Concentration to 2-foot depth ug/g	Frequency of Detection	95% UCL Concentration to 10-foot depth ug/g	Frequency of Detection	Background Concentration ug/g (a)	Risk-Based Concentration ug/g (b)
19	Aluminum	25557	4 of 4	8344	44 of 44	8604	794000
	Antimony	3128	4 of 4	231	4 of 44	3.8	110
	Arsenic	244	4 of 4	21.6	44 of 44	5.24	0.363
	Barium	25678	4 of 4	2195	44 of 44	233	13700
	Cadmium	641	3 of 4	48.7	3 of 44	3.05	127
	Chromium (d)	43.9	3 of 4	10.7	4 of 44	32.7	19
	Copper	109139	4 of 4	7908	4 of 44	1300	10100
	Lead	3908	4 of 4	325	44 of 44	500	500
	Mercury	3.11	2 of 4	0.247	2 of 44	0.056	81.9
	Nickel	43.2	3 of 4	11.7	12 of 44	12.6	470
	Potassium	3610	4 of 4	2544	44 of 44	2179	Not applicable (c)
	Silver	3.4	3 of 4	0.356	10 of 44	0.038	1370
	Sodium	1160	4 of 4	599	44 of 44	978	Not applicable (c)
	Zinc	211239	4 of 4	15685	40 of 44	94	54800
	1,3,5-TNB	143	2 of 4	12	6 of 48	NSA	1.05
	2,4,6-TNT	36045	3 of 4	2376	8 of 48	NSA	1.64
	2,4-DNT	NA		1.39	1 of 48	NSA	0.0723
	2,6-DNT	NA		0.87	1 of 48	NSA	0.0723
	RDX	NA		3.5	5 of 48	NSA	5.81
	Nitrate/nitrite	11.2	4 of 4	13	18 of 48	9.9	438000
21	None	NDB		NDB			
31	Barium	315	4 of 4	160	35 of 35	233	13700
	Copper	NA		6695	10 of 43	1300	10100
	Iron	55390	4 of 4	23117	35 of 35	26233	Not applicable (c)
	Lead	39	4 of 4	9.02	41 of 43	500	500
	Mercury	NA		0.066	1 of 43	0.056	81.9
	Nickel	NA		22.2	10 of 43	12.6	470
	Silver	0.461	2 of 4	0.139	8 of 43	0.038	1370
	Sodium	29731	4 of 4	5180	35 of 35	978	Not applicable (c)
	Zinc	554	4 of 4	138	40 of 43	94	54800
	1,3,5-TNB	16	1 of 4	1.66	1 of 35	NSA	1.05
	2,4,6-TNT	2180	2 of 4	197	2 of 35	NSA	1.64
	2,4-DNT	2.08	1 of 4	0.38	1 of 35	NSA	0.0723
	2,6-DNT	NA		0.135	1 of 43	NSA	0.0723
	RDX	3.08	2 of 4	0.548	2 of 35	NSA	5.81
	Tetryl	2.07	1 of 4	0.519	1 of 35	NSA	211
	Nitrate/nitrite	46.2	4 of 4	54	27 of 43	9.9	438000
	Trichloroethylene	NA		0.014	2 of 42	NSA	58
	Xylenes	NA		0.002	2 of 34	NSA	354000
	2-Methylnapthale	NA		0.155	1 of 35	NSA	Not applicable (c)
	Phenanthrene	0.45	1 of 4	0.153	3 of 43	NSA	Not applicable (c)
	Dieldrin	0.083	1 of 4	1.71	3 of 35	NSA	0.0399
	DDE	0.518	2 of 4	0.051	4 of 35	NSA	1.88
	DDT	0.423	1 of 4	0.042	2 of 35	NSA	1.88
	Endrin	NA		0.005	1 of 35	NSA	82.1
321	Copper	304	1 of 4	NA		1300	10100
	Lead	177	4 of 4	NA		500	500
	Potassium	4045	4 of 4	NA		2179	Not applicable (c)
	Silver	0.104	4 of 4	NA		0.038	1370
	Zinc	1030	4 of 4	NA		94	54800
	2,4-DNT	1.33	3 of 4	NA		NSA	0.0723
	Nitrate/nitrite	28	4 of 4	NA		9.9	438000

Table 1-2. Summary of Contaminants of Concern in Soil (continued)

Site	Contaminant of Concern	95% UCL Concentration to 2-foot depth ug/g	Frequency of Detection	95% UCL Concentration to 10-foot depth ug/g	Frequency of Detection	Background Concentration ug/g (a)	Risk-Based Concentration ug/g (b)
32II	Aluminum	9967	4 of 4	NA		8604	794000
	Antimony	30.6	2 of 4	NA		3.8	110
	Barium	23274	4 of 4	NA		233	13700
	Copper	5133	3 of 4	NA		1300	10100
	Lead	1263	4 of 4	NA		500	500
	Magnesium	16820	4 of 4	NA		8585	Not applicable (c)
	Potassium	2487	4 of 4	NA		2179	Not applicable (c)
	Silver	631	3 of 4	NA		0.038	1370
32II	Zinc	741	4 of 4	NA		94	54800
	2,4-DNT	1.61	1 of 4	NA		NSA	0.0723
	Nitrate/nitrite	26	4 of 4	NA		9.9	438000
38	Copper	4270	1 of 10	831	3 of 50	1300	10100
	Iron	28363	10 of 10	24518	50 of 60	26233	Not applicable (c)
	Mercury	0.237	1 of 10	0.065	1 of 50	0.056	81.9
	Nickel	20.4	2 of 10	9.64	3 of 50	12.6	470
	Potassium	2207	10 of 10	1818	50 of 50	2179	Not applicable (c)
	Silver	0.056	6 of 10	0.032	25 of 50	0.038	1370
	Zinc	2752	10 of 10	965	50 of 50	94	54800
	2,4,6-TNT	0.381	1 of 10	2.71	6 of 50	NSA	1.64
	Tetryl	NA		0.452	2 of 50	NSA	211
41	Antimony	8.41	2 of 2	7.31	6 of 10	3.8	110
	Lead	16.3	2 of 2	11.2	10 of 10	500	500
	Zinc	99.5	2 of 2	132	10 of 10	94	54800
55	RDX	NA		1.42	4 of 12	NSA	5.81
56	Beryllium	2.76	1 of 3	1.85	1 of 6	1.86	0.148
	Lead	10.3	3 of 3	7.86	6 of 6	500	500
	Magnesium	NDB		8936	6 of 6	8585	Not applicable (c)
57I	Lead	45.6	1 of 1	11.8	17 of 17	500	500
	Mercury	0.137	1 of 1	0.043	1 of 17	0.056	81.9
	Potassium	2240	1 of 1	1543	17 of 17	2179	Not applicable (c)
	Zinc	163	1 of 1	74.5	14 of 17	94	54800
57II	Lead	170	3 of 3	24.8	23 of 23	500	500
	Mercury	5.1	3 of 3	0.816	3 of 23	0.056	81.9
	Nickel	23.5	1 of 3	8.33	1 of 23	12.6	470
	Potassium	2360	3 of 3	1673	23 of 23	2179	Not applicable (c)
	Silver	0.459	3 of 3	0.069	6 of 23	0.038	1370
	Zinc	390	3 of 3	105	21 of 23	94	54800
	Tetryl	2.02	1 of 3	0.561	1 of 23	NSA	211
57III	Cadmium	5.82	1 of 8	2.31	1 of 40	3.05	127
	Copper	181	1 of 8	57.1	1 of 40	1300	10100
	Lead	149	8 of 8	30.9	40 of 40	500	500
	Mercury	0.058	1 of 8	0.031	1 of 40	0.056	81.9
	Potassium	2073	8 of 8	1415	40 of 40	2179	Not applicable (c)
	Silver	199	8 of 8	36.4	15 of 40	0.038	1370
	Zinc	5870	8 of 8	1137	40 of 40	94	54800
	2,4,6-TNT	NA		0.268	1 of 40	NSA	1.64

Table 1-2. Summary of Contaminants of Concern in Soil (continued)

Site	Contaminant of Concern	95% UCL Concentration to 2-foot depth ug/g	Frequency of Detection	95% UCL Concentration to 10-foot depth ug/g	Frequency of Detection	Background Concentration ug/g (a)	Risk-Based Concentration ug/g (b)
58	None	NDB		NA			
59	None	NDB		NA			
60	Lead	11.4	3 of 3	NA		500	500
	Silver	0.048	3 of 3	NA		0.038	1370

UCL - Upper Confidence Limit
NDB - No samples detected above background
NA - Not analyzed at this depth
NASA - No standard available

(a) - Background concentration as established in RI
(b) - Risk-based concentrations representing an excess cancer risk level of 1E-06 or a hazard quotient of 1. These data are discussed in Section 1.2.5.5 of this report and are presented here for future reference only.
(c) - Not applicable because either (1) calculated level greater than 1E+06 ppm or (2) health effects data unavailable (see Table 1-9)
(d) Total chromium

Source: Reference 4

In identifying contaminants in soil, it was assumed that soil at depths greater than 10 feet would not be available for exposure; therefore, only soils collected from 10 feet or shallower were included in this analysis.

From the information presented in Tables 1-1 and 1-2, the following is observed:

- Of the sites for which ground water was sampled and analyzed, Site 59 does not contain contaminants of concern in ground water (note that ground water was not characterized at Sites 7, 17,21, 32, 56, 58, and 60 – typically because of the proximity of these sites to others where ground water was characterized).

- Of all the ADA sites, Sites 7, 58, and 59 do not contain contaminants of concern in soil.

Note that the contaminants presented in Tables 1-1 and 1-2 reflect only those contaminants that are classified as contaminants of concern based on the above criteria. Subsequent assessments to determine and identify contaminants that contribute to unacceptable risk are summarized on a site-by-site basis in Section 2.3.2, Estimated Areas and Volumes of Contaminated Media Requiring Remediation.

1.2.5.2 Toxicity Assessment. The purpose of the toxicity assessment is to qualitatively and quantitatively assess the toxicological hazards of the contaminants of concern as a function of the anticipated route of exposure (e.g., ingestion or inhalation).

Toxicological profiles were developed as part of the RA and are included in the Appendix of that document. The profiles include the following information (when such information is available): noncarcinogenic effects and reference doses for oral ingestion and inhalation; carcinogenic effects, slope factors and weights-of-evidence for oral ingestion, dermal absorption, and inhalation; and references.

Quantitative toxicity data are presented in terms of reference doses and slope factors. Reference doses (RfD) values are used to evaluate noncarcinogenic effects. RfDs are derived from "no-observed-adverse-effect levels" (NOAELs), which represent the highest experimental exposure level at which a particular critical toxic effect is not observed.

Cancer slope factors (SF) are used to evaluate potential human carcinogenic risks. An SF is defined as an estimate of the upper 95 percent confidence limit of the slope of the dose-response curve extrapolated to low doses, and is considered to be a measure of the cancer causing potential of a chemical. RfDs and SFs are provided for both ingestion and inhalation exposure pathways.

Toxicity values used in the RA were obtained from the Integrated Risk Information System (IRIS), the Health Effects Assessment Summary Tables (HEAST), EPA Region

III toxicity criteria, the Public Health Risk Evaluation Database, Drinking Water Criteria documents, Ambient Water Quality criteria documents, Air Quality Criteria documents, and Agency for Toxic Substances and Disease Registry (ATSDR) toxicity profiles.

Toxicity values used in the RA are summarized in Table 1-3 for contaminants of concern identified in ground water and soil at the ADA.

1.2.5.3 Exposure Assessment. The purpose of the exposure assessment is to: identify potential human and environmental receptors; identify and evaluate potential current and future exposure pathways; and determine the extent of exposure under site-specific current and future land use scenarios. The following 12 potential exposure pathways were identify for current and future receptors at UMDA as well as in the vicinity of the installation:

Pathway	Description
1	Dermal contact with contaminated soil
2	Inadvertent ingestion of contaminated soil
3	Inhalation of contaminated soil as airborne dust
4	Inhalation of vapors volatilized from soil
5	Ingestion of contaminated drinking water
6	Inhalation of volatile contaminants emitted from ground water during showering
7	Dermal contact with contaminated ground water during showering
8	Dermal contact of contaminated ground water during non-showering use
9	Inhalation of vapors during non-showering use of ground water
10	Consumption of game that feeds on vegetation that grows in contaminated soil
11	Consumption of livestock (or their milk) that feed on vegetation growing in contaminated soil and/or that consume contaminated ground water
12	Consumption of crops irrigated by contaminated ground water and/or grown in contaminated soil

Pathways were reviewed for both current and future land use. Under current land use conditions, it was assumed that two receptors exist: UMDA employees and nearby residents.

Specific receptors identified for future land use are dependent on the selected use. Scenarios considered for future land use include: residential, industrial, military, agricultural, and recreation. Of the possible future land uses, residential land use generally yields the highest exposures because of the long exposure frequency and

Table 1-3: Summary of Toxicity Criteria for the Contaminants of Concern

Chemical	RfDo (mg/kg/day)	RfDi (mg/kg/day)	SFo	SFi
TAL Inorganics				
Aluminum	2.90E+00	ND	ND	ND
Antimony	4.00E-04	ND	ND	ND
Arsenic	3.00E-04	UR	1.75E+00	1.40E+01
Barium	7.00E-02	1.40E-04	ND	ND
Beryllium	5.00E-03	ND	4.3+00	8.40E+00
Cadmium	5.00E-04	UR	ND	6.30E+00
Chromium VI	5.00E-03	6.00E-07	ND	4.25E+01
Cobalt	1.00E-05	2.86E-04	ND	ND
Copper	3.70E-02	1.00E-02	ND	ND
Iron	ND	8.60E-03	ND	ID
Lead	UBK Model	ID	ID	ID
Magnesium	ID	ID	ID	ID
Manganese	1.00E-01	1.00E-04	ND	ND
Mercury (inorganic)	3.00E-04	9.00E-05	ND	ND
Nickel	2.00E-02	UR	ND	8.40E-01
Potassium	ID	ID	ID	1.70E+00
Selenium	5.00E-03	ID	ID	ID
Silver	5.00E-03	ID	ID	ID
Sodium	ID	ID	ID	ID
Thallium	8.00E-05	ND	ID	ID
Vanadium	7.00E-03	ND	ND	ND
Zinc	2.00E-01	ND	ND	ND
Cyanide (free)	2.00E-02	ND	ND	ND
1,3,5-Trinitrobenzene	5.00E-05	ND	ND	ND
1,3-Dinitrobenzene	1.00E-04	ND	ND	ND
2,4,6-TNT	5.00E-04	ND	3.00E-02	ND
2,4-DNT	2.00E-03	ND	6.80E-01	ND
2,6-DNT	1.00E-03	ND	6.80.10-1	ND
HMX	5.00E-02	ND	ID	ND
RDX	3.00E-03	ND	1.10E-01	ND
Nitrobenzene	5.00E-04	6.00E-04	ND	ND
Tetryl	1.00E-02	ND	ND	ND
Other Inorganics				
Nitrate	1.60E+00	ND	ND	ND
Nitrite	1.00E-01	ND	ND	ND
TCL Volatiles				
Benzene	UR	UR	2.90E-02	2.90E-02
Trichloroethylene	UR	UR	1.10E-02	6.00E-03
Xylenes (total)	2.00E+00	1.00E-01	ND	ND
TCL Semi-Volatiles				
2-Methylnaphthalene	ID	ID	ID	ID
Naphthalene	4.00E-03	ND	ND	ND
Phenanthrene	ND	ND	ND	ND
Pesticides/PCBs				
Dieldrin	5.00E-05	ND	1.60E+01	1.60E+01
DDD	ND	ND	2.40E-01	ND
DDE	ND	ND	3.40E-01	ND
DDT	5.00E-04	ND	3.40E-01	3.40E-01
Endrin	3.00E-04	ND	ND	ND

ND - no data
ID - insufficient data available
UR - under review
RfDo - oral ingestion reference dose
RfDi - inhalation reference dose
SFo - oral ingestion slope factor
SFi - inhalation slope factor
UBK - uptake/biokinetic

Source: Reference 4

Note: Sources and references for the toxicity criteria presented are cited in Reference 4

duration for this population. Therefore, the residential scenario is assumed to be the most conservative future scenario and the most appropriate land use to consider when estimating risks or hazards.

At the ADA, the future military use of the sites by the Oregon National Guard for tank training exercises was evaluated in addition to residential future use. In this scenario, only pathway 3 (inhalation of contaminated soil as airborne dust) was considered.

Pathways that were excluded from consideration at a specific site were done so using the following rationale:

- Sampling was not performed because the medium and/or contaminant was not considered to be of concern.
- The contaminant source applicable to the specific pathway has been shown to not exist based on sampling results.
- The transport mechanism for the pathway does not exist at the site.
- The receptor does not exist at the site.
- The exposure route cannot exist at the site for other reasons.

In addition, on a site-by-site basis, certain pathways may not have been quantified because: (1) the exposure resulting from the pathway is much less than that from another analogous pathway; (2) the potential magnitude of the exposure is low; or (3) the probability of the exposure occurring is very low.

Pathways included for quantification for the ADA are summarized in Table 1-4 for current land use and Table 1-5 for future land use.

For each quantified pathway, an average daily intake is calculated using a variety of assumptions including: receptor body weight; frequency of exposure; exposure duration; respiration rates; absorption factors; skin surface areas; and ingestion rates. For detail regarding specific parameters that are included in the individual pathways, refer to the RA.

1.2.5.4 Human Health Risk Evaluation. The purpose of the human health risk characterization is to relate exposure estimates to toxicity to estimate the potential health hazards and/or risks posed by the contaminated media.

The risk characterization is conducted by combining the toxicological data with the average daily intakes. For the ADA pathways, potential incremental cancer risks (risks) are calculated by multiplying the daily intake averaged over the receptor's lifetime by the SF. According to the NCP, acceptable exposure levels resulting from these calculations are generally those that represent an excess upperbound lifetime cancer risk to an individual of between 1×10^{-4} and 1×10^{-6}.

Table 1-4: Exposure Pathways Quantified at the ADA - Current Land Use Scenario

Site No.	Exposure Pathway 1	2	3	4	5	6	7	8	9	10	11	12
7, Aniline Pit	I	I	I	I	I	I	I	I	I	I	I	I
8(a), Acid Pit	I	I	I	I	I	I	I	I	I	I	I	I
13(a), Smoke Canister Disposal Area	I	I	I	I	I	I	I	I	I	I	I	I
14(a), Flare and Fuse Disposal/Bird Cage Are	I	I	I	I	I	I	I	I	I	I	I	I
15(a), TNT Sludge Burial and Burn Area	I	I		I	I	I	I	I	I	I	I	I
16, Open Detonation Pits	I	I		I	I	I	I	I	I	I	I	I
17, Above Ground Open Detonation Area	I	I	I	I	I	I	I	I	I	I	I	I
18, Dunnage Pits	I	I		I	I	I	I	I	I	I	I	I
19, Open Burning Trenches/Pads	I	I		I	I	I	I	I	I	I	I	I
21, Missile Fuel Storage Areas	I	I		I	I	I	I	I	I	I	I	I
31(a), Pesticide Pits	I	I		I	I	I	I	I	I	I	I	I
32 I, Open Burning Trays	I	I		I	I	I	I	I	I	I	I	I
32 II, Open Burning Trays	I	I		I	I	I	I	I	I	I	I	I
38(a), Pit Field Area	I	I		I	I	I	I	I	I	I	I	I
41, GB/VX Decon Solution Burial Areas	I	I		I	I	I	I	I	I	I	I	I
55(a), Trench/Burn fields	I	I	I	I	I	I	I	I	I	I	I	I
56, Munitions crate burn area	I	I	I	I	I	I	I	I	I	I	I	I
57 I, Former pit area locations	I	I		I	I	I	I	I	I	I	I	I
57 II, Former pit area locations	I	I		I	I	I	I	I	I	I	I	I
57 III, Former pit area locations	I	I		I	I	I	I	I	I	I	I	I
58, Burrow/burn/disposal area	I	I	I	I	I	I	I	I	I	I	I	I
59, GB/VX Decon solution disposal areas	I	I	I	I	I	I	I	I	I	I	I	I
60, Active firing range	I			I	I	I	I	I	I	I	I	I

I - The pathway is incomplete for the reasons discussed in text.

[shaded box] Indicates that the exposure pathway was quantified for the site.

Source: Reference 4 and Arthur D. Little, Inc.

Table 1-5: Exposure Pathways Quantified at the ADA - Future Residential Land Use Scenario

Site No.	Exposure Pathway 1	2	3	4	5	6	7	8	9	10	11	12
7, Aniline Pit	I	I	I	I	I	I	I	I	I	I	I	I
8(a), Acid Pit	I	I	I	I				A	A	I	A	
13(a), Smoke Canister Disposal Area				I		I	I	I	I	I	A	
14(a), Flare and Fuse Disposal/Bird Cage Area	I			I		I	I	I	I	I	A	
15(a), TNT Sludge Burial and Burn Area				I		I	I	I	I	I	A	
16, Open Detonation Pits				I		I	I	I	I	I	A	
17, Above Ground Open Detonation Area				I	I	I	I	I	I	I	A	
18, Dunnage Pits	I			I		I	I	I	I	I	A	
19, Open Burning Trenches/Pads				I		I		A	I	I	A	
21, Missile Fuel Storage Areas	I			I	I	I	I	I	I	I	A	
31(a), Pesticide Pits				I				A	A	I		
32 I, Open burning trays				I	I	I	I	I	I	I	A	
32 II, Open burning trays				I	I	I	I	I	I	I	A	
38(a), Pit Field Area				I		I	I	I	I	I	A	
41, GB/VX Decon Solution Burial Areas	I			I		I	I	I	I	I	A	
55(a), Trench/Burn fields	I	I	I	I		I	I	I	I	I	A	
56, Munitions crate burn area	I			I	I	I	I	I	I	I	A	
57 I, Former pit area locations	I			I		I	I	I	I	I	A	
57 II, Former pit area locations				I		I	I	I	I	I	A	
57 III, Former pit area locations	I			I		I	I	I	I	I	A	
58, Burrow/burn/disposal area	I	I	I	I	I	I	I	I	I	I	I	
59, GB/VX Decon solution disposal areas	I	I	I	I	I	I	I	I	I	I	I	
60, Active firing range	I			I	I	I	I	I	I	I	A	

I - The pathway is incomplete for the reasons discussed in text.
A - The pathway is excluded from quantification because the expected exposure risks are much less than from another pathway involving the same medium and exposure point.

Shading indicates that the exposure pathway was quantified for the site.

Source: Reference 4 and Arthur D. Little, Inc.

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Hazard quotients (HQ) are calculated for noncarcinogenic risks by dividing the average daily intake by the RfD. Risks and HQs are calculated for each pathway and then summed to yield the total site risk and HQ. Human health hazards related to exposure are generally considered of concern when the HQ exceeds 1.

It is acknowledged that the total risks and HQ for each pathway are probably overestimated, because combining risk and hazard quotients assumes the additivity of toxic effects within the human body when, in fact, chemicals with different mechanisms of toxic action may act independently[4].

In addition to the calculations described above, an uptake/biokinetic model was used in the RA to evaluate potential exposure to lead at the ADA sites. The evaluation was conducted for the various sites at UMDA where lead concentrations in soil exceed 200 ppm. The results of application of this model indicate that several sites have lead concentrations that may yield unacceptable exposure levels. The exact number of sites will depend on the percentage of the population to be protected and the blood lead cutoff level selected. The implications of this calculation will be presented in Section 1.2.5.5, Risk Based Remedial Action Criteria.

1.2.5.4.1 Current Land Use Scenarios. A summary of risk and hazards estimated under current land use conditions at UMDA (including the ADA sites) is presented in Table 1-6. These risks and hazards reflect those imposed on the 11 receptor populations quantitatively evaluated in the baseline RA as shown. Of the current receptors, the highest risks and hazards apply to the OD pit/open burning tray workers, whose multiple pathway risk and hazard are $8x10^{-7}$ and $2x10^{-1}$, respectively. These values are below the levels of concern (cancer risk less than $1x10^{-6}$ and HQ less than 1).

1.2.5.4.2 Future Land Use Scenarios. A summary of risks and hazards calculated for ADA sites at which contaminants of concern were identified is presented in Table 1-7 for both residential and military future use. As shown in Table 1-5 (summary of pathways quantified for each site), risks and hazards were calculated in the RA for crop and/or game ingestion (pathways 10, 11, and 12). Risks associated with these ingestion pathways are not included in the quantification of risks and hazards for the ADA in accordance with guidance from EPA and DEQ[18]. Table 1-7 reflects this deletion.

The risks and hazards summarized in Table 1-7 indicate the following:

- For future residential use, risks and hazards are below a cancer risk of $1x10^{-6}$ and/or HQ of 1 at Sites 21 and 60; these risks and/or hazards are exceeded at all other sites.

- For future residential use, risks and hazards are below a cancer risk of $1x10^{-5}$ and/or HQ of 1 at Sites 21, 32I, 56, and 60; these risks and/or hazards are exceeded at all other sites.

Table 1-6: Summary of Total Risks and Hazard Quotients for Current Land Use Scenarios

Receptor	Pathway(s) (a)	Risk	HQ
1. Worker-Near Explosives Washout Area at Building 419	Dust inhalation (3)	$8x10^{-8}$	$9x10^{-3}$
2. Open detonation pit and open burning tray workers	Dust inhalation (3)	$8x10^{-7}$	$2x10^{-1}$
3. Target range users	Incidental soil ingestion (2) and dust inhalation (3)	$1x10^{-9}$	$8x10^{-4}$
4. Worker in southwest warehouse area	Incidental soil ingestion (2) dust inhalation (3) and dermal contact with soil (1)	$4x10^{-8}$	$7x10^{-3}$
5. Worker near DRMO Building	Incidental soil ingestion (2), dust inhalation (3) and dermal contact with soil (1)	$2x10^{-8}$	$1x10^{-2}$
6. Pesticide worker	Inhalation of dust (3)	$5x10^{-10}$	$7x10^{-5}$
7. Workers at Buildings 612 and 617	Dermal contact with soil (1), soil ingestion (2), dust inhalation (3)	$2x10^{-7}$	$2x10^{-2}$
8. Eastern boundary residents	Dust inhalation (3)	$8x10^{-8}$	$8x10^{-3}$
9. Hermiston residents	Dust inhalation (3)	$6x10^{-8}$	$5x10^{-3}$
10. Western boundary residents	Dust inhalation (3)	$7x10^{-8}$	$3x10^{-2}$
11. Irrigon residents	Dust inhalation (3)	$1x10^{-8}$	$3x10^{-3}$

Risk - Incremental cancer risk
HQ - Hazard quotient
(a) - Pathway descriptions and numbers
Source: Reference 4 and Arthur D. Little, Inc.

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Table 1-7. Summary of Total Risks and Hazard Quotients for Future Use Scenarios
(With Risk and Hazard Contaminant Drivers for Residential Scenario)

Site	Residential					Military (a)	
	Pathways	Risk	Risk Drivers	HQ	Hazard Drivers	Risk	HQ
8	5,6,7	6E-04	As (>99%)	3	As (100%)	NC	NC
13	1,2,3,5	1E-03	As (98%), 26DNT (2%)	4	As(70%),Sb(11%),Zn(10%),Ba*,Cu*,V*	2E-07	0.02
14	2,3,5	7E-04	As(>99%)	4	As(75%),Sb(5%),Cr(7%),V(5%),Se*,Zn*,Ba*	2E-06	2
15	1,2,3,5	7E-04	As(52%), 246TNT(16%),Be(13%),Cr(15%),RDX*	200	Co(53%),Th(17%),246TNT(12%),Cr(9%),Cd(6%),As*	3E-04	200
16	1,2,3,5	6E-04	As(>99%)	10	Co(71%),As(20%),V(6%),246TNT*	4E-08	0.1
17	1,2,3	2E-05	Be(91%),246TNT(9%)	10	Co(97%),246TNT(3%)	4E-08	0.07
18	2,3,5	8E-04	As(>99%)	5	As(90%),Mn(4%),Al*,Ba*,Ni*,V*	6E-06	5
19	1,2,3,5,7	2E-02	246TNT(95%),As(5%)	3000	246TNT(95%),135TNB(3%),Sb*	7E-04	600
21	2,3	(b)		(c)		NC	NC
31	2,3,5,6,7	2E-03	246TNT(63%),As(34%),24DNT*	200	246TNT(94%),135TNB(5%),As*	8E-05	90
32I	1,2,3	2E-05	24DNT(>99%)	0.08	24DNT(37%),Cu(37%),Zn(25%)	(b)	0.0002
32II	1,2,3	2E-05	24DNT(>99%)	2	Ba(53%),Cu(25%),Sb(15%),Zn(5%),24DNT*	(b)	1
38	1,2,3,5	7E-04	As(>99%)	5	As(74%),Cu(10%),Sb(5%),V(5%),Zn*,Ba*,Cr*,Se*	6E-08	0.001
41	2,3,5	6E-04	As(94%),Be(6%)	3	As(77%),Sb(11%),V(8%),Ba*,Cr*,Mn*,Ni*	(b)	0
55	5	3E-04	As(100%)	2	As(91%),Sb(9%)	NC	NC
56	2,3	2E-05	Be(100%)	0.002	Be(100%)	7E-09	0
57I	2,3,5	6E-04	As(100%)	3	As(92%),V(3%),Ba*,Cr*,Mn*	(b)	5E-05
57II	1,2,3,5	6E-04	As(100%)	3	As(84%),Sb(8%),V(3%),Hg*,Ba*,Se*	4E-08	0.002
57III	2,3,5	6E-04	As(100%)	3	As(81%),Sb(5%),V(5%),Ag(3%),Zn(3%),Cd*Cu*,Hg*,Ba*	2E-07	0.001
60	2,3	(b)	Pb(100%)	0.3	Pb(>99%)	(b)	0

(a) Military Risks and Hazards calculated for Pathway 3 (Dust Inhalation) only
(b)Calculated risks less than 1E-06
(c)Calculated hazard quotient less than 1E-03
NC - Not Calculated
Percentages of contaminants drivers may not add to 100% due to rounding
*- indicates that contaminant contributes 1 to 2 percent of total risk or hazard

Source: Reference 4

- For future military use, risks and hazards are below a cancer risk of $1x10^{-6}$ and HQ of 1 at Sites 13, 16, 17, 32I, 38, 41, 56, 57I, 57II, 57III, and 60; these risks and/or hazards are exceeded at Sites 14, 15, 18, 19, and 31.

1.2.5.4.3 Ground Water at the ADA. The above discussion reflects contamination and resulting risks and hazards relating to both ground water and soil at the ADA. Although both media contribute to the overall risks and hazards, a few observations with respect to ground water at the ADA need to be discussed.

One of the conclusions of the RI was that the spread of contamination due to contaminants in the soil was through windblown dust. There was no evidence that migration of contaminants in soil was responsible, or would in the future be responsible, for ground water contamination beneath the ADA. This conclusion is supported by the general absence of any specific correlation between contaminants of concern in soil and ground water as well as the lack of evidence that contaminants of concern in ground water have any relation to activities performed at the ADA.

For the most part, ground water characterizations at the ADA indicated the presence of various levels of inorganic elements or compounds that were identified in background ground water chacterizations. In addition, these inorganics were consistently identified across the entire installation and were not restricted to the ADA.

Exceptions to the background inorganic contamination were three detected organics (1,3-dinitrobenzene at Site 19, RDX at Site 31, and benzene at Site 31). Each of these organics was detected in a single sample with a resulting upper 95 percent confidence limit concentration below detection limits in each case (refer to Section 3.0 of the RA). None of these organic contaminants were drivers of the risks and hazards of their respective sites.

The most notable of contaminants of concern in ground water is arsenic, which was detected in levels above background at all sites at which ground water was characterized (with the exception of Site 59). The presence of arsenic in ground water proved to be a driving factor in the determination of risks and hazards at a majority of sites. In fact, at Sites 8, 14, 38, 41, 55, 57I, 57II, and 60, it is the only contributor to total risks greater than $1x10^{-6}$ and total HQs greater than 1. In addition, in no instance was the concentration of arsenic in ground water (at the 95% percent confidence limit) greater than the maximum concentration limit of 50 μg/l.

Based on the observation discussed above, the remediation of ground water will not be addressed in this FS. Although ground water remediation will not be addressed, its contribution to the total risks and hazards as imposed by exposure pathways 5, 6, and 7 will be continued throughout the FS. To illustrate the impact of these pathways on the total risks and hazards associated with future residential use, Table 1-8 has been prepared to reflect a breakdown of risks and hazards associated with specific ground water-related and non-ground water-related exposure pathways.

From Table 1-8, it can be seen that regardless of the contribution of contaminated soil (represented by exposure pathways 1, 2, and 3), ground water-related risks and hazards exceed the future residential use criteria (risk of $1x10^{-6}$ and HQ of 1) at Sites 8, 13, 14, 15, 16, 18, 19, 31, 38, 41, 55, 57I, 57II, and 57III. It should be noted, however, that these exceedences are due to the presence of arsenic in the ground water which, in all cases, is below the maximum concentration limit of 50 µg/l.

The above observation implies that even if soil is cleaned to the degree that exposure pathways 1, 2, and 3 no longer pose unacceptable risk or hazards, the total site risks and hazards quantified for the site will exceed the risk ($1x10^{-6}$) and HQ (1) criteria at these sites. However, in no case will the total risk exceed $7x10^{-4}$ or the total HQ exceed 4.

1.2.5.5 Risk Based Remedial Action Criteria. For each of the land use scenarios, risk-based preliminary remediation goals (PRGs) were developed as part of the RA. Risk-based PRGs indicate acceptable residual contaminant concentrations based on the following target human health risk values: incremental cancer risks equal to 10^{-6} ; and hazard quotients equal to 1. The risk-based PRGs are back-calculated from the target risk levels for each contaminant in each media. Risk-based PRGs are not calculated for the current land use scenario because all current cancer risks and HQs fall below the target values of 10^{-6} (cancer risk) and 1.0 (HQ).

The single exception to this method of calculation of risk-based PRGs is lead. An action level of 500 µg/g has been established for lead at the ADA[18]. Based on the uptake/biokinetic model used in the RA to evaluate potential exposure to lead, a residual concentration of 500 µg/g would result in 92% of children having blood lead levels of less than or equal to 10 µg/dL and greater than 99.5% of the children would have blood lead levels of less than or equal to 15 µg/dL.

A summary of risk-based PRGs calculated for contaminants in soil at the ADA is presented in Table 1-9. Note that only risk-based PRGs for contaminants in soil are provided since it has been determined that ground water remediation will not be addressed in this FS (see Section 1.2.5.4.3, Ground Water at the ADA).

One point of note with respect to the risk-based PRGs presented in Table 1-9 is that, in several instances (barium, cadmium, and chromium, for example), risk-based PRGs for the light industrial and military use scenarios are considerably lower than those for the residential use scenario. This is in contrast to the general assumption that the residential use scenario provides the most conservative approach. Based on these "anomalies," this assumption may not always be the case. Examination of the calculations involved in determining the risks and hazards associated with ingestion and inhalation of contaminated dust confirms this. In these calculations, it was assumed that future light industrial workers or military personnel involved in training would be located and performing routine activities closer to the source of dust emissions and therefore would be exposed to higher concentrations of contamination. For the protection of such

Table 1-8. Detail of Future Residential Use Risks and Hazard Quotients

	Total (a)			Ground Water-Related			Non-Ground Water-Related		
Site	Pathways	Risk	HQ	Pathways	Risk	HQ	Pathways	Risk	HQ
8	5,6,7	6E-04	3	5,6,7	6E-04	3	None		
13	1,2,3,5	1E-03	4	5	6E-04	3	1,2,3	5E-05	0.9
14	2,3,5	7E-04	4	5	7E-04	4	2,3	8E-07	0.2
15	1,2,3,5	7E-04	200	5	3E-04	2	1,2,3	4E-04	200
16	1,2,3,5	6E-04	10	5	6E-04	3	1,2,3	9E-07	7
17	1,2,3	2E-05	10	None			1,2,3	2E-05	10
18	2,3,5	8E-04	5	5	8E-04	4	2,3	2E-05	0.6
19	1,2,3,5,7	2E-02	3000	5	4E-04	4	1,2,3	2E-02	300
21	2,3	(b)	(c)	None			2,3	(b)	(c)
31	2,3,5,6,7	2E-03	200	5,6,7	6E-04	3	1,2,3	1E-03	0.02
32-I	1,2,3	2E-05	0.08	None			1,2,3	2E-05	0.08
32-II	1,2,3	2E-05	2	None			1,2,3	2E-05	2
38	1,2,3,5	7E-04	5	5	7E-04	4	1,2,3	2E-07	0.5
41	2,3,5	6E-04	3	5	6E-04	3	2,3	(b)	0.08
55	5	3E-04	2	5	3E-04	2	None		
56	2,3	2E-05	0.002	None			2,3	2E-05	0.002
57-I	2,3,5	6E-04	3	5	6E-04	3	2,3	(b)	0.005
57-II	1,2,3,5	6E-04	3	5	6E-04	3	1,2,3	2E-08	0.09
57-III	2,3,5	6E-04	3	5	6E-04	3	2,3	1E-05	0.3
60	2,3	(b)	0.3	None			2,3	(b)	0.3

(a) Numbers may not add due to rounding
(b) Calculated risks less than 1E-06
(c) Calculated hazard quotient less than 1E-03

Source: Reference 4

Table 1-9. Risk-Based Preliminary Remedial Goals for Contaminants of Concern in Soil

	Future Use Scenario				
Contaminant of Concern	Residential Risk-based (a) ug/g	Light Industrial Risk-based (b) ug/g	Light Industrial Risk-based (c) ug/g	Military Risk-based (d) ug/g	Military Risk-based (e) ug/g
Aluminum	274000	NA	NA	NA	NA
Antimony	110	818	818	876	876
Arsenic	0.363	0.898	8.98	8.02	80.2
Barium	13700	861	861	923	923
Beryllium	0.148	0.809	8.09	7.22	72.2
Cadmium	127	2.75	27.5	24.6	246
Chromium	19	0.413	3.71	3.68	3.98
Cobalt	2.74	20.2	20.2	21.6	21.6
Copper	10100	75600	75600	81000	81000
Iron	-	-	-	-	-
Lead	(f)	(f)	(f)	(f)	(f)
Magnesium	-	-	-	-	-
Manganese	15200	617	617	661	661
Mercury	81.9	292	292	313	313
Nickel	470	10.2	102	91	910
Potassium	-	-	-	-	-
Selenium	1370	10200	10200	10900	10900
Silver	1370	10200	10200	10900	10900
Sodium	-	-	-	-	-
Thallium	21.9	164	164	175	175
Zinc	54800	409000	409000	438000	438000
Cyanide	5480	40900	40900	43800	43800
Nitrate/nitrite	438000	NA	NA	NA	NA
Trichloroethylene	58	441	4410	3940	39400
Xylenes	354000	382000	382000	399000	399000
2-Methylnapthalene	-	-	-	-	-
Phenanthrene	-	-	-	-	-
135 TNB	1.05	2.27	2.27	2.43	2.43
246 TNT	1.64	4.24	22.7	24.3	24.3
24 DNT	0.0723	0.187	1.87	1.67	16.7
26 DNT	0.0723	0.187	1.87	1.67	16.7
HMX	1050	2270	2270	2430	2430
RDX	5.81	52	520	465	4650
Nitrobenzene	10.5	22.6	22.6	24.2	24.2
Tetryl	211	454	454	487	487
DDD	2.66	23.8	238	213	2130
DDE	1.88	16.8	168	150	1500
DDT	1.88	12.7	127	113	1100
Dieldrin	0.0399	0.269	2.69	2.4	24
Endrin	82.1	613	613	657	657

A dashed entry (-) indicates that relevant health effects criteria are unavailable
NA - Not Applicable because calculated PRG is greater than 1E+06 ppm
(a) Based on a Residential cancer risk of 1E-06 or an HQ of 1
(b) Based on a Light Industrial cancer risk of 1E-06 or an HQ of 1
(c) Based on a Light Industrial cancer risk of 1E-05 or an HQ of 1
(d) Based on a Military cancer risk of 1E-06 or an HQ of 1
(e) Based on a Military cancer risk of 1E-05 or an HQ of 1
(f) Action level for lead established at 500 ug/g

Source: Reference 4

workers and personnel, the soils where the dust originates would have to be less contaminated (with respect to specific contaminants) than would be required for residents. Modeled air concentrations supporting these observations are provided in Appendix E, Table E-6 of the RA.[4]

1.2.6 Ecological Risk Assessment

The following discussion provides a brief summary of the Ecological Assessment (EA) performed for UMDA as presented in the Draft Final Ecological Assessment Report [19]. For a detailed account of the EA, refer to the referenced EA report.

The EA involved the conduct of a multi-step process to evaluate the affects and potential affects to site biota from contaminants in soil at UMDA. These steps included[19]:

- Evaluation of site activities resulting in the chemical releases
- Characterization of the installation physical features, habitats, potentially exposed biota and identification of indicator species
- Observation of habitat disruptions potentially related to toxic effects
- Identification of contaminants of concern and potential exposure pathways
- Summarization of environmental fate for the contaminants of concern
- Assessment of the exposure and toxicity potential of contaminants of concern to selected indicator species
- Characterization of risk

The toxicity and environmental fate of contaminants of concern were evaluated on an installation-wide basis for contaminants found at or near the surface. Thirty contaminants of concern were identified at locations at which wildlife might be exposed. These contaminants of concern were identified as those contaminants that were above background soil levels or not naturally occurring in the environment as determined in the RI. The 30 contaminants of concern identified in the EA include metals, nitroaromatic compounds (explosives and their derivatives), and pesticides. Of these, the most significant in terms of volume, distribution and relative toxicity, are lead; zinc; aluminum; 2,4,6-TNT; HMX; RDX; and tetryl [19].

The potency of the contaminants of concern to environmental receptors (indicator species) was calculated based on exposure point concentrations and certain assumptions concerning the duration of exposure. A full discussion of these calculations and assumptions is provided in the EA report.

The chronic toxicity imposed by the contaminants of concern was developed by comparing calculated daily contaminant uptake rates to NOAELs for four indicator species. The indicator species selected for use in these calculations were the field mouse, the pronghorn antelope, the American badger, and the Swainson's hawk.

Daily contaminant uptake rates were calculated for the oral ingestion pathway only. These calculations were based on a total ingestion dose as a function of contaminant concentration in soil and the species ingestion rate of soil. Specific ingestion pathways considered include:

- Feeding on vegetation
- Feeding on prey in intimate contact with the soil
- Preening
- Burrowing
- Direct ingestion by soil licking or eating (to obtain available salts contained in the soil)

Exposure potentials for the indicator species at the ADA were determined and are summarized as follows:

- Field Mouse - The field mouse has a home range that is significantly smaller than the areal distribution of contaminated soils at the ADA. For this reason, the field mouse may be directly and continuously exposed to the contaminants where its range is coincident with contamination. However, since many of the contaminated sites offer neither food nor cover, they may be less desirable as a home range for the field mouse.

- Pronghorn - Present exposure potential for the pronghorn is zero at the ADA due to their exclusion from the area by a high fence.

- Badger - Badgers have a large home range, estimated at several times larger than the areal extent of contamination. They may be occasionally exposed to acutely toxic doses of contaminants if they seek prey in the most contaminated sites of the ADA. Because of their large home ranges, it is suggested that chronic exposures would be unlikely.

- Swainson's hawk - The contaminated areas at UMDA represent about 10 percent of the overall hunting range of this hawk. The hawk is a migratory species and therefore only a transient resident at UMDA. In addition, preferred habitat is found in abundance off site. For these reasons, acute exposure potential is expected to be low and chronic exposure potential may be minuscule.

The only indicator species for which potential future exposures may differ from current exposures described above is the pronghorn. In the event fence removal occurs at the ADA in the future, the introduced pronghorn would be either moved to another reservation or harvested. Native deer might then be exposed to the contaminated sites. Surface salts formed by constituent degradation might occasionally encourage soil eating behavior that could result in acute exposure to toxicants or intermittent chronic exposures.[19]

Hazard quotients (HQs), represented by the ratio of the contaminant intake to the NOAEL, were calculated. An HQ of greater than one is indicative of the possibility of adverse health effects resulting from exposure to a specific contaminant.

A summary of the risk characterization performed for the principal contaminants of concern at the ADA (as identified in the EA) is presented in Table 1-10. As can be seen, contaminants at Sites 15, 19, and 31 present the greatest concern in terms of magnitude of worst-case HQs. In order to determine the variability in individual site HQs, median values of HQ were determined for selected site/contaminant/species combinations as shown in Table 1-10. Note that these median values are significantly less than the worst-case values (in fact, often the median values were 0 or close to 0) indicating that the worst-case values are not representative of the ADA as a whole[19].

Table 1-10. Risk Characterization Summary for the Principal Contaminants of Concern at the ADA

Indicator Species	Principal Contaminant of Concern	Worst-Case Chronic HQ (Site)	Median HQ	Comments
Field Mouse				Home range for mice is typically smaller than the area of an individual site.
	Lead	397 (19)	16.2	Lead is the most ubiquitous contaminant of concern at the ADA.
	Zinc	98.5 (19)		
	Barium	95.8 (19)		
	Antimony	43.4(15)		
	Cobalt	18.8(15)		HQ calculated from background soil concentrations suggest a slight health risk from exposure; probable explanation is the inadequacy of the database.
	Cadmium	9.09(15)	0	Potential neurotoxic and nephrotoxic effects minimal compared to effects of lead.
	RDX	497(15)	0	Acute HQ supports conclusions for chronic HQ.
	TNT	178(31)	0	Acute HQ supports conclusions for chronic HQ.
	TNB	76.9(31)		Absence of database makes toxicity criteria almost meaningless.
Pronghorn				Pronghorns are prevented from entering the ADA due to a high restraining fence.
Badger				Home range for badgers is approximately twice the size of the ADA. Rodents were used as surrogate animals to calculate HQ for Cu, Sb, and Co.
	Copper	209.0(19)	0.3	Surrogate species may have been unusually sensitive to Cu.
	Barium	85.8(19)	0	
	Antimony	38.9(15)		
	Lead	36.9(19)		
	Zinc	18.1(19)		
	Cobalt	16.6(15)		
	TNT	195.0(31)	0	
Hawk				Contaminated sites are only about 2 % of the migratory hawk's home range and the sites are probably not preferred hunting grounds for the hawk.
	Lead	179(19)	4.45	
	Cadmium	131(15)	0	
	Chromium	28.6(15)		

HQ - Hazard quotient

Source: Reference 19

2.0 Identification and Screening of Technologies

2.1 Introduction

The primary objective of this phase of the FS is to develop an appropriate range of technology types and process options that will protect human health and the environment by eliminating, reducing, and/or controlling risks posed by the contaminated media. These technology types and process options are then assembled into remedial alternatives (Section 3.0, Development of Alternatives) that are then assessed in the detailed analysis (Section 4.0, Detailed Analysis of Alternatives).

Prior to the development of technology types and process options, remedial action objectives that specify the contaminants and media of concern, exposure pathways, and preliminary remediation goals were developed. The preliminary remediation goals were selected based on the ARARs and the Human Health Baseline Risk Assessment [4].

Once the remedial action objectives were developed, the volume of contaminated soil to be remediated was estimated based on the results of the RI [2]. Using the estimated amount of soil to be remediated and the developed remedial action objectives, potential technologies and process options were identified and screened to eliminate those technologies that were not applicable to remediate the site. Applicable process options were then identified and evaluated for effectiveness, implementability, and cost. This procedure resulted in the selection of technology types and process options to be incorporated into the remedial alternatives.

The detailed description of the technology identification and screening phase is presented in the remaining sections following the outline provided by EPA in the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*[3].

2.2 Remedial Action Objectives

The development of remedial action objectives is a critical step in the FS process because they are the basis by which technologies and process options will be evaluated. The development of remedial action objectives involves addressing the following: 1) contaminants of concern; 2) Applicable or Relevant and Appropriate Requirements (ARARs); 3) allowable exposures based on the risk assessment; and 4) development of remedial action goals.

2.2.1 Contaminants of Concern

Contaminants of concern at the ADA are those contaminants that were identified in the remedial investigation(s) and met certain criteria. The selection of contaminants of concern is described in detail in Section 1.2.5.1, Selection of Contaminants of Concern. Summaries of contaminants of concern identified for each site of the ADA (in both ground water and soil) are provided in Tables 1-1 and 1-2.

It should be noted that the presence of a contaminant of concern at a site is not necessarily an indication that the site will require remediation. Site remediation requirements will depend on the remedial goals that are established. These remedial goals will be discussed in Section 2.2.4, Development of Remedial Action Goals.

The remainder of this FS primarily addresses issues relating to the remediation of soil at the ADA. The remediation of ground water will not be addressed for the reasons described in Section 1.2.5.4.3, Ground Water at the ADA. Although ground water remediation will not be addressed, its contribution to the total risks and hazards imposed by contaminated media at the ADA sites will be carried throughout the FS.

In general, the types of contaminants of concern in ADA soils include metals, explosives, and other organics. Contamination of soil by metals at a wide range of concentrations occurs virtually at every site at the ADA. Organic contamination is less widespread and typically, organic concentrations are very low.

2.2.2 Applicable or Relevant and Appropriate Requirements (ARARs)

The selection of ARARs is dependent on the hazardous substances present at the site, the site characteristics and location, and the actions selected for a remedy. Consequently, ARARs are characterized as follows:

- Chemical-specific
- Location-specific
- Action-specific

Chemical-specific ARARs are health- or risk-based concentration limits set for specific hazardous substances, pollutants, or contaminants. Location-specific ARARs address physical environmental conditions such as the presence of wetlands on the site or the location of 100-year floodplains. Action-specific ARARs control or restrict particular types of remedial actions as alternatives for cleanup.

2.2.2.1 Chemical-Specific ARARs. In developing chemical-specific ARARs, both state and federal regulations were considered. These chemical-specific ARARs are summarized in Table 2-1.

Federal ARARs - Soil

Resource Conservation And Recovery Act (RCRA) - There are no set maximum allowable residual levels for contaminants in soils under federal law. RCRA addressed land disposal of treated hazardous wastes in its land disposal restrictions found in 40 CFR 268. Soil and debris that are contaminated with prohibited wastes are subject to the land disposal restrictions and must meet the treatment standard for the contaminating

Table 2-1: Chemical-Specific Applicable or Relevant and Appropriate Requirements (ARARs)

Medium/ Authority	Requirement	Status	Requirement Synopsis	Action to be Taken to Attain ARAR
Federal Regulatory Requirements	RCRA Land Disposal Restrictions (LDR) (40 CFR 268)	Applicable	Remedial activities that involved the movement of excavated materials to a new location and placement in or on land or that generate residual hazardous wastes will trigger land disposal restrictions. Soil and debris contaminated with prohibited wastes must meet the treatment standard for the contaminated waste prior to land disposal.	Any wastes subject to LDR must be treated using best demonstrated available treatment technologies for each hazardous constituent in each listed or characteristic waste.
State Regulatory Requirements	Oregon Hazardous Substance Remedial Action Rules	Applicable	Requires that if hazardous substances are released, the environment shall be restored to background conditions if feasible.	Background conditions are to be met unless background conditions are not feasible. If background conditions are not feasible, the environment is to be restored to the lowest levels that are protective (in terms of public health, safety, and welfare and the environment) and feasible.

waste prior to land disposal. However, EPA realizes that certain problems are associated with regulating hazardous wastes in soil. Because of such problems, EPA is preparing a separate rule making that will establish treatability groups and treatment standards for contaminated soil. Until contaminated soil can be better organized into treatability groups, however, promulgated treatment standards for the individual or types of wastes would be applicable ARARs.

Since some of the remedial options could involve treatment of the soil and subsequent land disposal, the RCRA land disposal requirements would be an applicable ARAR and subject the treatment to meeting chemical-specific treatment standards. The applicability of RCRA is discussed in Section 2.2.2.3, Action-Specific ARARs.

State ARARs - Soil

Oregon Soil Cleanup Standards - The Oregon Hazardous Substance Remedial Action Rules (OAR 340-122)[20] provide guidance for determining contaminant cleanup levels on a site-specific basis. These rules have been identified as applicable for the remediation of contaminated soil.

These rules state that in the event of a release of a hazardous substance, the environment shall be restored to:

- Specific Numerical Soil Cleanup Levels as specified in OAR 340-122-04, if applicable, or

- Background levels unless is it determined that remedial actions designed to attain Background Level do not meet the certain "feasibility " requirements in which event the environment shall be restored to the lowest concentration level in accordance with OAR 340-122-090, which provides guidance for remedial action selection

Of the general types of contaminants of concern at the ADA (metals and organics), the organics can be considered to be not naturally occurring. Therefore, the background concentration would be essentially zero or, for practical purposes, below detection limits. If a remedial alternative proposed in this FS cannot achieve background, a risk assessment approach must be used to demonstrate that the action achieves the lowest cleanup level that protects human health and the environment.

2.2.2.2 Location-Specific ARARs. Location-specific ARARs set restrictions on remedial action activities depending upon the characteristics of a site and/or its immediate environs. These ARARs are contained in a number of federal statutes and regulations. In addition, the state of Oregon has requirements that may apply in a given situation.

Regulations that may be considered as location-specific ARARs for UMDA are summarized in Table 2-2.

In addition to the ARARs discussed in each of the following sections, consideration should also be given to the local planning requisites in both Morrow and Umatilla Counties. Oregon law mandates that each county and community develop, and have approved by the state, a comprehensive land use plan that must take into consideration many of the same concerns addressed in this discussion. Consultation with the appropriate county officials and cognizance of their land use plans and goals would increase the efficacy of any actions proposed or taken at UMDA.

Federal ARARs

Caves, Salt-dome Formations, Salt-bed Formations, and Underground Mines. The bedrock under UMDA and the surrounding area consists of basalt laid down by lava flows during the Miocene Period. This is capped by a mixture of Pleistocene alluvial deposits, including clays, sands, silts, gravels, and some boulders. There are sedimentary interbeds between the lava flows and this type of rock also has tunnels and occasional "lava holes." However, there are no indications of caves, salt-dome formations, salt bed formations or underground mines on the site, nor would such features normally be expected with a structural bedrock of basaltic lava flows. Thus no ARARs are identified for this category.

Faults. UMDA is surrounded by four structural features: the Service Anticline on the east, an anticline on the west, the Dalles-Umatilla Syncline to the north, and a monocline to the south. The Service anticline runs north to south and is faulted on both its east and west dips. There are active Holocene faults approximately 50 to 80 miles north of the site, near the Hanford Nuclear Reservation in Washington State. There is also a suspected active Holocene fault approximately 70 miles southeast of the depot near LeGrand, Oregon. However, none of the faulting associated with the Service Anticline is documented or believed to have been displaced during the Holocene period, nor is it considered active.

Because of the history of low seismicity in the surrounding area, UMDA is exempted from compliance with the RCRA seismic requirements of 40 CFR 264.18. 40 CFR 264.18(a) stipulates that all facilities located within political jurisdictions other than those listed in Appendix VI are assumed to be in compliance for location of new treatment, storage, or disposal (TSD) facilities. Oregon is not listed in this Appendix, thus the location-specific standards in 40 CFR 264.18(a) for siting a hazardous waste treatment, storage, or disposal facility are not an ARAR.

Table 2-2: Location-Specific Applicable or Relevant and Appropriate Requirements (ARARs)

Medium/ Authority	Requirement	Status	Requirement Synopsis	Action to be Taken to Attain ARAR
Federal Regulatory Requirements	Clean Water Act (CWA) Section 404(b) (40 CFR 230; 33 CFR 320-330)	Applicable if Wetlands are Affected	No discharge of dredged or fill material shall be permitted if there is a practical alternative that has less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences. Appropriate and practical steps must be taken that will minimize the potential adverse impacts on the aquatic ecosystem.	There will be no discharge of dredged or fill materials into wetlands.
	Endangered Species Act (16 USC 1531 et seq.; 40 CFR 502)	Applicable	This Act requires the conservation of endangered and threatened species within critical habitats.	The U.S. Fish and Wildlife Service will be consulted to determine whether remedial actions are likely to jeopardize any endangered or threatened species. No remedial actions will proceed that will negatively affect endangered or threatened species.

Wilderness Areas, Wildlife Refugees, and Scenic Rivers. There are no designated wilderness areas within UMDA, or in its immediate vicinity. Neither the Columbia River nor the Umatilla River, both of which lie within 3 miles of the depot, have been designated as scenic rivers.

*Wetlands and Floodplains.*The Columbia River is now largely dam-controlled, thus eliminating most concerns with flooding hazards. Available information indicates that UMDA is not located within 100- or 500-year floodplains and therefore no ARARs were identified in this category.

There are a number of wetlands in the immediate area of UMDA, to the east, west, and south. Those associated with the Umatilla River on the east come within at least 1 mile of the site. Additionally, the wetlands located near the northwest corner of the depot extend to the boundary of the UMDA. Wetlands located to the west of UMDA are associated with Irrigon State Wildlife Refuge and those to the south are 2.5 to 3.5 miles from the depot.

At the federal level, the ARARs pertinent to wetlands include Section 404 of the Clean Water Act (CWA) and Executive Order 11990 on Wetlands Protection. Since remediation activities at UMDA will not include the discharge of dredged or fill material, as defined in 33 CFR 323.2(d), Section 404 of the CWA is not applicable. However, a guiding principle of 40 CFR Part 230 is that degradation or destruction of wetlands should be avoided to the extent possible. Executive Order 11990 requires federal agencies to minimize the destruction, loss, or degradation of wetlands and preserve and enhance natural and beneficial values of wetlands.

Since none of the identified wetlands are actually on the site, there would be no applicable ARARs specifically for on-site actions unless remedial actions have the potential to affect wetlands adjacent to (off-site) UMDA.

Rare, Threatened, or Endangered Species. The UMDA installation is part of the critical winter range of both the bald eagle (Haliaeetus leucocephalus) and the golden eagle (Aquila chrystaetos). The former is on the federal endangered and threatened species list and both are protected under the Fish and Wildlife Coordination Act. The peregrine falcon (*Falcon peregrinus*), another federally endangered species, has been sighted in the vicinity of UMDA, and the installation is considered part of its critical habitat. One of three small habitats along the Columbia River where the long-billed curlew (*Numenius Americanus*) still breeds is located on the installation. The species is on the federal "Candidate" list. No federal or state threatened or endangered plants have been identified at UMDA[21].

The Endangered Species Act (ESA) of 1973, 16 USC §1531 *et seq.* provides a means for conserving various species of fish, wildlife, and plants that are threatened with extinction. The ESA defines an endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range." In addition, the ESA defines a threatened species as "any species which is likely to become an endangered species within the foreseeable future." Further, the ESA provides for the designation of critical habitats, that are "specific areas within the geographical area occupied by the [endangered or threatened] species ... on which are found those physical or geological features essential to the conservation of the species."

Section 7 of the ESA requires consultation with the U.S. Fish and Wildlife Service to determine whether the project is likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of a critical habitat on or off the site. Since federally listed endangered and threatened species are associated with the UMDA installation, the ESA is an applicable ARAR and any action that would affect any endangered or threatened species, or adversely impact a species' critical habitat, would be subject to the requirements of the ESA.

Artifacts and Historical and Archeological Sites. There are two known historic buildings at UMDA, the headquarters building and the firehouse building. There are also two potential archeological resources at UMDA that have been tentatively identified: a portion of the Oregon Trail and a prehistoric site. None of the activities at the ADA sites will affect these locations, so there are no ARARs for this category.

State ARARs

Wilderness Areas, Wildlife Refuges, and Scenic Rivers. There are three wildlife refuges in very close proximity to the depot: Cold Spring National Wildlife Refuge at 15 miles, Umatilla National Wildlife Refuge at 8 miles, and Irrigon State Wildlife Refuge at 12 miles. The latter of these refuges, Irrigon, is protected under state law and is considered a sensitive environment. It is one of the primary wetlands in this region and supports a major waterfowl wintering habitat. State regulations exclude or restrict certain activities in this area, including activities that deter, distract, or hinder the peaceful enjoyment of the area.

There would be no applicable ARARs for on-site actions because the UMDA itself is not located within a refuge. However, the proximity of Irrigon State Wildlife Refuge and its potential hydrological connection to UMDA cautions careful analysis of any actions that might impact that system.

Wetlands and Floodplains. Activities in a wetland involving the alteration (removal, fill, etc.) of 50 cubic yards or more are subject to approval of the Division of State Lands. Since there are no wetlands on the UMDA site, state wetlands law is not an ARAR.

2.2.2.3 Action-Specific ARARs. Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. On-site CERCLA response actions must only comply with the substantive requirements of regulations, and not the administrative requirements [CERCLA 121(e)]. In the UMDA Federal Facility Agreement, UMDA itself is defined as the site. Therefore, in the event that the following remedial alternatives for ADA sites are considered to take place on UMDA, none of the permitting requirements of RCRA, the Clean Air Act (CAA), etc., are considered as ARARs. The remedial actions involving treatment of contaminated soil under consideration for the ADA are: 1) incineration; 2) stabilization/solidification; and 3) soil washing. A review of potential action-specific ARARs relevant to these actions is provided in Table 2-3.

Federal ARARs - Waste
CERCLA § 121 establishes a preference for remedial actions involving treatment that permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants at the site. RCRA requirements for treatment of hazardous wastes apply at a CERCLA site only if: the waste is a RCRA listed or characteristic waste; and the CERCLA activity constitutes treatment of RCRA hazardous waste, as defined under RCRA.

A number of remedial alternatives would result in the RCRA regulations being considered as action-specific ARARs. Under 40 CFR 261.3, any solid waste derived from the treatment, storage, or disposal of a listed hazardous waste remains that listed waste. Many of the wastes deposited at the UMDA site were deposited prior to November 19, 1980 (when RCRA was enacted), and thus were not subject to RCRA at the time of deposition. However, EPA asserts that RCRA requirements apply to any waste materials disposed of prior to 1980 when those materials are managed, treated, and/or disposed of in the present (55 FR 8762). A number of the contaminants of concern at UMDA are thus considered hazardous waste, once the process of managing, treating, and/or disposing of them begins.

A variety of activities or actions commonly performed during a CERCLA cleanup action may be sources of air emissions. These activities include incineration and handling of contaminated soil (e.g., digging and relocating soil). Many of the sources of gaseous

Table 2-3: Action-Specific Applicable or Relevant and Appropriate Requirements (ARARs)

Medium/ Authority	Medium	Requirement	Status	Requirement Synopsis	Action to be Taken to Attain ARAR
Federal Regulatory Requirements	Air	Resource Conservation and Recovery Act (RCRA) (40 CFR 264, Subpart AA)	Relevant and Appropriate depending on concentration of emission	Regulations contain air emission standards for process vents, closed vent systems, and control devices at RCRA hazardous waste treatment, storage, or disposal facilities.	The remedial alternative shall meet the requirements of these regulations.
	Air	RCRA (40 CFR 264, Subpart O)	Potentially Applicable	Regulations for RCRA hazardous waste incinerators set forth operating requirements and performance standards.	Remedial alternatives that employ thermal destruction will comply with this regulation.
	Waste	RCRA, Identification and Listing of Hazardous Waste (40 CFR 261.3)	Applicable	Requires that wastes be analyzed to determine if they represent RCRA hazardous wastes based on established lists and hazardous waste characteristics such as reactivity and toxicity.	Waste analyses will be required of contaminated, excavated soils. These regulations will be used to define which wastes at UMDA are considered RCRA hazardous.
	Waste	RCRA, Land Disposal Restrictions (LDR) (40 CFR 268)	Applicable	Prohibits the disposal of RCRA hazardous waste in the land unless treatment standards are met or a treatability variance is obtained.	Remedial activities that involve the movement of excavated materials to a new location and placement in or on land or that generate residual hazardous wastes will trigger LDR. Any wastes subject to LDR must be treated using best demonstrated available treatment technologies for each hazardous constituent in each waste.

Table 2-3: Action-Specific Applicable or Relevant and Appropriate Requirements (ARARs) (continued)

Medium/ Authority	Medium	Requirement	Status	Requirement Synopsis	Action to be Taken to Attain ARAR
Federal Regulatory Requirements (continued)	Waste	RCRA, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR 264)	Applicable	This regulation establishes the minimum national standards for management of RCRA hazardous wastes for owners and operators of facilities that treat, store, or dispose of RCRA hazardous waste.	Treatment of hazardous waste may involve various forms of treatment. The design and operating standards for specific treatment units will be met: 40 CFR 264.190-264.192 (tank systems); 40 CFR 264.221 (surface impoundments); 40 CFR 264.251 (waste piles); 40 CFR 264.273 (land treatment units); 40 CFR 264.601 (miscellaneous treatment units).
	Waste	RCRA, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR 264 Subpart G)	Applicable	This regulation establishes closure requirements for RCRA hazardous waste management facilities.	Remedial actions that involve on-site treatment, storage, or disposal will require closure plans.
	Waste	Federal Facility Compliance Act of 1992	Applicable	The act specifies that EPA and the Department of Defense establish when military munitions become a hazardous waste.	Remedial actions that involve the removal of munition items (including UXO) from soil must comply with this act.
State Regulatory Requirements	Air	Oregon Air Pollution Control Regulations (OAR Chapter 340)	Applicable	These regulations set limits on particulate and gaseous emissions.	Remedial actions will be designed and operated to comply with applicable emission limitations.
	Waste	Oregon Hazardous Waste Management Regulations (OAR Chapter 340, Divisions 100-108)	Applicable	These regulations establish state standards for closure of surface impoundments and are more stringent than the federal closure standards.	Remedial activities that involve closure of a surface impoundment on site will comply with this regulation. All wastes will be removed prior to closure.

Table 2-3: Action-Specific Applicable or Relevant and Appropriate Requirements (ARARs) (continued)

Medium/ Authority	Medium	Requirement	Status	Requirement Synopsis	Action to be Taken to Attain ARAR
State Regulatory Requirements (continued)	Air	Oregon Air Pollution Control Regulations	Applicable	These regulations prescribe control and treatment requirements for potential sources of air contamination.	Activities involving the generation of air emissions may fall under these regulations (including soil excavation and handling and incineration of contaminated soil). Appropriate controls will be maintained during these activities to comply with these regulations.
Non-Regulatory Criteria Advisories and Guidance to be Considered	Waste	EPA Interim Policy for Planning and Implementing CERCLA Response Actions. Proposed Rule 50 FR 45933 (November 5, 1985)	To be Considered	This policy addresses the need to consider treatment, recycling, and reuse before off-site land disposal is used. Prohibits use of a RCRA facility for off-site management of Superfund hazardous substances if the facility has significant RCRA violations.	This policy will be considered prior to any off-site management of hazardous substances.

and particulate matter emissions may be subject to federal or state regulations. In addition, control devices and some cleanup activities that increase the amount of emissions, or change the type (e.g., flares, air strippers, or excavation) may be considered sources subject to air emission requirements contained in the Clean Air Act (CAA) or RCRA.

Soil as Hazardous Waste. Under 40 CFR 261.3, any solid waste derived from the treatment, storage, or disposal of a listed or characteristic hazardous waste remains that listed or characteristic waste. Because the varied demolition and disposal activities that occurred throughout the ADA may have involved hazardous wastes based on the characteristics of reactivity or toxicity, soils contaminated with those wastes are suspect as RCRA hazardous wastes.

The RCRA characteristic for reactivity may be considered an ARAR for soil containing explosives or UXO, once that soil is excavated. This is based on the following definitions of a reactive material: it is capable of detonation or explosive reaction if it is subjected to a strong initiating force or if heated under confinement [40 CFR 261.23(a)(6); or it is readily capable of detonation or explosive decomposition or reaction at standard temperature or pressure [40 CFR 261.23(a)(7)]. The former definition may apply to UXO present in the excavated soil; if so, then these UXO will be subject to RCRA as a characteristic reactive waste. The Federal Facility Compliance Act of 1992 states that EPA and the Department of Defense will propose regulations identifying when military munitions become hazardous wastes. These regulations are to be promulgated in 1994.

Extensive testing performed by the Army to identify the reactivity characteristics of soil contaminated with explosives indicated that: (a) soil containing less than 15 percent explosives will not react positively to induced shock; and (b) soil containing less than 12 percent explosives will not react explosively when subjected to submerged flame initiation[22]. As a conservative guideline, the Army typically uses a total explosives concentration of 10 percent as a control limit for initial consideration of reactivity. Analyses of the soils at various ADA sites indicate an average of 0.2 percent explosives at sites where they are present with a maximum detected of about 4 percent. Based on reactivity, therefore, RCRA requirements are not applicable to soils contaminated with explosives alone.

Since it is also possible that unused pesticides (e.g., DDE, DDT, dieldrin, and endrin) were disposed of at UMDA, a waste analysis for RCRA P- and U-listed wastes will have to be conducted. Under 40 CFR 261.30, a solid waste is a RCRA hazardous waste if it is listed in 40 CFR 261 Subpart D (Lists of Hazardous Wastes). If any P- or U- listed

wastes are found to be present in soils, the requirements of RCRA pertinent to these wastes would be an ARAR.

Further assessment of the applicability of RCRA to contaminated soils at the ADA is required with respect to the toxicity characteristic because of the prevalence of heavy metals (including lead, cadmium, arsenic, barium, selenium, chromium, mercury, and silver) and 2,4-DNT at the sites. If the soil exhibits the RCRA toxicity characteristic based on the Toxicity Characteristic Leaching Procedure (TCLP) (40 CFR 261.24), then that soil is a RCRA hazardous waste. For example, at Site 15, TNT Sludge Burial and Burn Area, the TCLP was performed on soil because of the apparent likelihood that residues from the deactivation furnace were disposed there. Results of the TCLP indicated that concentrations of lead and cadmium were in excess of standards. These results indicate that these soils exhibit the RCRA toxicity characteristic based on TCLP and are thus D006 (for cadmium) and D008 (for lead) listed hazardous wastes (40 CFR 261.24). In addition, these wastes may be subject to the RCRA land disposal restrictions (LDR) as described below.

For the purpose of further identifying the toxicity characteristics of contaminated soil at the ADA, it will be assumed that lead concentrations of greater than 900 μg/g will cause soil to exhibit the toxicity characteristic for lead. This value was identified as a result of tests performed in the development of the FS for the UMDA Deactivation Furnace Site and reported in that FS report[23]. Concentrations of lead in excess of 900 μg/g were found in ADA soils at Sites 15, 17, 19, and 32II.

Because toxicity characteristics of contaminated soil were not fully developed for all of the potential toxic contaminants, waste analyses and TCLP will be required to fully determine the toxicity characteristics and the applicability of LDR to these soils.

Land Disposal Restrictions. Hazardous waste or hazardous waste residue may be subject to restrictions on land disposal under 40 CFR 268. There are no maximum allowable residual levels for contaminants in soils under federal law. RCRA addressed land disposal of treated hazardous wastes in its land disposal restrictions in 40 CFR 268. EPA has not yet established separate treatment standards for contaminated soil, thus, it follows that until then, contaminated soils would have to meet the treatment standard for the regulated contaminating waste. However, EPA has determined that the LDRs are generally inappropriate or unachievable for soil and debris from a CERCLA response action, and recommend a treatability variance for such soils (55 FR 8760). EPA has published guidelines for obtaining a treatability variance for soil and contaminated debris with RCRA hazardous waste (OSWER Directive 9347.3-06FS, July 1989).

LDRs do not apply to circumstances in which the waste is treated within a unit and thus would not be ARARs for actions taken within the ADA. In the event that the contaminated soil or treatment residue is considered for removal from the ADA for treatment or disposal, the LDR may apply.

If the hazardous waste is treated so that extract from the treated material does not exceed the TCLP toxicity characteristic threshold for any of the constituents for which it was characteristic, the material would no longer be designated a hazardous waste. In terms of ARARs, the treated, formerly hazardous waste would now be a nonhazardous waste and may be disposed of on site or within a permitted solid waste facility.

Design and Operating Requirements. In general, various requirements of 40 CFR Part 264 will be applicable ARARs for remedial actions at UMDA. Any RCRA hazardous waste treatment unit (e.g., incinerator) must be designed and operated in accordance with the applicable RCRA regulations. Applicable RCRA ARARs include 40 CFR 264 Subpart I (container storage), 40 CFR 264 Subpart N (landfills), and 40 CFR 264 Subpart O (incinerators). In addition, any hazardous waste and hazardous waste residues that remain after treatment must be further treated or disposed of in accordance with RCRA. Any RCRA hazardous wastes shipped off site for treatment, storage, and/or disposal are subject to the full requirements of RCRA.

Closure Requirements. Upon completion of treatment, storage, and disposal activity, the hazardous waste treatment, storage, or disposal units must be closed and all hazardous waste and hazardous waste residues removed from the site according to the applicable regulations of 40 CFR 264 Subpart G.

Federal ARARs - Air

With regard to air emissions, any technology employed in the remedial action would have to be designed and operated so that emissions of pollutants into the air do not exceed limits established in the regulations.

Under the federal Clean Air Act National Ambient Air Quality Standards (NAAQS) program, EPA established ceilings for certain criteria pollutants, called ambient air quality standards. The six criteria pollutants are lead, nitrogen dioxide, ozone, PM-10, carbon monoxide, and sulfur dioxide. EPA has established a list of all geographic areas in compliance with the NAAQS (attainment areas) as well as those not in compliance with NAAQS (nonattainment areas). UMDA is located in a geographical area designated attainment for all six criteria pollutants. Attainment areas are subject to the Prevention of Significant Deterioration (PSD) regulations. The PSD program requires an owner or operator of a major new source or modification of an existing major source located in an attainment area to obtain a permit before construction or modification and comply with

best available control technology (BACT). The purpose of this permitting is to prevent significant degradation of air quality. The PSD regulations are considered to be not applicable to any remedial action at UMDA because emissions from such actions will not qualify as a major source.

The 1990 CAA Amendments required states to develop permitting programs for major sources and certain other sources regulated under the CAA. The deadline for state permitting programs has not bee reached yet, however, CERCLA on-site actions are not subject to the administrative procedures and permit requirements.

Regulations under RCRA address air pollutant emissions from activities that may occur at UMDA (e.g., incineration). The regulations for hazardous waste incinerators (40 CFR 264 Subpart O) set operating requirements for the incinerator and performance standards for destruction and removal efficiency for principal organic hazardous constituents (PHOCs). This regulation would be considered an applicable ARAR for thermal destruction remediation technology for the treatment of contaminated soil. Proposed amendments to this regulation (55 FR 17862 [April 27, 1990]) establish a more stringent performance standard for hydrogen chloride and may constitute guidance To Be Considered (TBC).

Subpart AA of 40 CFR 264 contains air pollutant emission standards for process vents, closed-vent systems, and control devices at hazardous waste treatment, storage, and disposal facilities. These regulations are applicable to equipment associated with air or steam stripping operations that treat substances that are RCRA hazardous wastes and that have a total organics concentration of 10 parts per million by weight (ppmw) or greater. It establishes performance standards for total organic emissions from these operations. These regulations will be applicable for remedial action activities at UMDA where total organic concentrations exceed 10 ppmw. These regulations will be not be ARARs if the total organic concentration is less than 10 ppmw or if the organics are from nonhazardous sources.

State ARARs - Waste

Hazardous Waste. The Oregon Hazardous Waste Management Regulations (OAR Chapter 340 Divisions 100-108) reference the RCRA regulations for treatment, storage, and disposal, and therefore, are not repeated in this discussion. However, the closure requirements in Oregon are more stringent than the federal program in that they require the removal of all wastes, etc., at closure (the federal program gives the option of closing with wastes left in place).

State ARARs - Air

Emission Limitations. Certain sections of the Oregon Air Pollution Control Regulations (OAR Chapter 340) should be considered ARARs because the state air regulations set emission limits for the amounts of certain pollutants emitted into the atmosphere. Applicable Oregon ARARs include those requirements that limit emissions of particulate matter (OAR 340-21) and gaseous emissions (OAR 340-22). Remedial actions such as incineration have the potential to emit contaminants into the air. Any remediation technology would have to be chosen, designed, and operated based upon its ability to comply with the applicable emission standard.

2.2.2.4 Clearance of Unexploded Ordnance. As a result of ordnance disposal and related operations, unexploded ordnance (UXO) are present in unknown quantities and at unknown locations at the surface and in the subsurface at the ADA. Army regulations are currently being prepared to address the type and degree of UXO clearance for specific future land uses[24]. Once these regulations are promulgated, they would be considered an Army ARAR for remediation of the ADA. In the absence of specific regulations or guidance, proposed standards for clearance and associated risks have been developed. These standards are presented in Table 2-4.

As shown in Table 2-4, unlimited land use, including urban development, would require the removal of all ordnance items to the maximum depth possible. Alternative uses such as livestock grazing, recreation, and agriculture would be limited use activities with less severe requirements for clearance. In addition, continued use of the impacted area for military use would most likely require only surface clearance to allow for maneuvers, target maintenance, and associated activities[25]. Since these standards are proposed only, for the purpose of this FS, they are designated To Be Considered (TBC).

2.2.3 Allowable Exposures Based on Risk

In Section 1.2.5, Baseline Risk Assessment, a summary of the Human Health Baseline Risk Assessment was provided. This summary included the various aspects involved in the identification of current and future exposure pathways at the ADA, as well as the development of risks and hazards imposed by the contaminated media at ADA on future use of the area. One of the products of the RA was a comprehensive set of risk-based preliminary remediation goals (PRGs). These risk-based PRGs were presented in Table 1-9 for contaminants of concern in soil at the ADA based on a number of future use scenarios. These PRGs represent the risk-based input to the development of remedial action goals.

Table 2-4. Proposed UXO Clearance Standards and Associated Risks for Various Land Uses

End-Use	Clearance Standard	Risks
Restricted game refuge, disposal site, firing range, restricted area. Acceptable land uses may change depending on time.	Fence and Post	Encroachment. Possible future clearance requirement before natural processes render ordnance safe.
Wilderness parks, livestock grazing, limited human foot traffic depending on hazards, military use.	Surface Clearance	Depending on clearance effectiveness and ordnance type, some hazards may exist from shallow buried items. On inert or practice ordnance targets, the risks are minimal.
Limited agriculture, tree farming, limited recreational vehicle use and foot traffic, parking areas, hunting, fishing.	Surface and Shallow Subsurface Clearance to 18 inches	If land is distrubed or eroded, there exists the possibility of exceeding the clearance depth and exposing ordnance.
Unlimited agriculture, tree farming, recreation. Limited construction (i.e., sheds, temporary buildings, pipelines).	Clearance to a minimum depth of 10 feet	If land is disturbed or eroded, there exists the possibility of exceeding the clearance depth and exposing ordnance.
Large structures, drilling, mineral exploration, mining, etc. may be performed in areas cleared.	Remove all ordnance	A hazard of encountering and ordnance item would exist during excavation or construction. There exists little chance of an explosive incident caused by a deeply buried ordnance item from surface activity.

Source: Reference 25

2.2.4 Development of Remedial Action Goals

Potentially applicable remedial goals for the cleanup of contaminated soils at the ADA are presented in Table 2-5. The numerical goals presented in Table 2-5 reflect risk-based remedial goals as well as background concentrations. For reference, certified reporting limits for the individual contaminants, as reported in the RI, are included in this table.

The ultimate goal of remedial action at the ADA is to provide a mechanism for protecting human health and the environment from exposure to contaminated soils and unexploded ordnance. Based on the previous discussions and the potentially applicable remedial goals presented in Table 2-5, remedial action objectives include:

- If feasible, reduce contaminant concentrations in soil to background levels or certified reporting limits; or

- Reduce the total excess cancer risk to $1x10^{-6}$ and the noncarcinogenic hazard to a hazard quotient of 1 for soil to which human exposure is likely; or

- If reduction of contaminant levels to background, certified reporting limits, or $1x10^{-6}$ total excess cancer risks is not feasible, reduce excess cancer risks to the lowest feasible level within the range of $1x10^{-4}$ to $1x10^{-6}$ with the final level to be determined based on feasibility and cost;

- Remove all UXO as necessary to permit remedial action; and

- Remove UXO from the ADA to the degree necessary to minimize risks associated with future use.

Numerical cleanup levels corresponding to the above objectives for each of the contaminants of concern in soil at the ADA are presented in Table 2-6. Risk-based numerical levels correspond to a future use of residential and a residual risk of $1x10^{-6}$ or a HQ of 1.

Although specific remedial goals were not developed as part of the Ecological Assessment (EA), it is felt that the numerical cleanup levels provided in Table 2-6 are responsive to the findings of the EA as summarized in Section 1.2.6, Ecological Assessment.

Table 2-5. Potentially Applicable Remedial Goals for Contaminants of Concern in Soil

Contaminant of Concern	CRLs(a) ug/g	Background(b) ug/g	Risk-Based Remedial Goals: Residential Risk-based (c) ug/g	Light Industrial Risk-based (d) ug/g	Light Industrial Risk-based (e) ug/g	Military Risk-based (f) ug/g	Military Risk-based (g) ug/g
Aluminum	14.1	8604	274000	NA	NA	NA	NA
Antimony	3.8	3.8	110	818	818	876	876
Arsenic	0.25	5.24	0.363	0.898	8.98	8.02	80.2
Barium	29.6	233	13700	861	861	923	923
Beryllium	1.86	1.86	0.148	0.809	8.09	7.22	72.2
Cadmium	3.05	3.05	127	2.75	27.5	24.6	246
Chromium	12.7	32.7	19	0.413	3.71	3.68	3.98
Cobalt	15	15	2.74	20.2	20.2	21.6	21.6
Copper	58.6	58.6	10100	75600	75600	81000	81000
Iron	50	26233	NA	NA	NA	NA	NA
Lead	6.26	8.37	(h)	(h)	(h)	(h)	(h)
Magnesium	50	8585	NA	NA	NA	NA	NA
Manganese	0.275	874	15200	617	617	661	661
Mercury	0.05	0.056	81.9	292	292	313	313
Nickel	12.6	12.6	470	10.2	102	91	910
Potassium	37.5	2179	NA	NA	NA	NA	NA
Selenium	0.25	0.25	1370	10200	10200	10900	10900
Silver	0.025	0.038	1370	10200	10200	10900	10900
Sodium	150	978	NA	NA	NA	NA	NA
Thallium	31.3	31.3	21.9	164	164	175	175
Zinc	30.2	94	54800	409000	409000	438000	438000
Cyanide	0.242	0.92	5480	40900	40900	43800	43800
Nitrate/nitrite	0.6	9.9	438000	NA	NA	NA	NA
Trichloroethylene	0.003	NSA	58	441	4410	3940	39400
Xylenes	0.002	NSA	354000	382000	382000	399000	399000
2-Methylnapthalene	0.049	NSA	NA	NA	NA	NA	NA
Phenanthrene	0.033	NSA	NA	NA	NA	NA	NA
135 TNB	0.488	NSA	1.05	2.27	2.27	2.43	2.43
246 TNT	0.456	NSA	1.64	4.24	22.7	24.3	24.3
24 DNT	0.424	NSA	0.0723	0.187	1.87	1.67	16.7
26 DNT	0.085	NSA	0.0723	0.187	1.87	1.67	16.7
HMX	0.666	NSA	1050	2270	2270	2430	2430
RDX	0.587	NSA	5.81	52	520	465	4650
Nitrobenzene	2.41	NSA	10.5	22.6	22.6	24.2	24.2
Tetryl	0.731	NSA	211	454	454	487	487
DDD	0.008	NSA	2.66	23.8	238	213	2130
DDE	0.008	NSA	1.88	16.8	168	150	1500
DDT	0.007	NSA	1.88	12.7	127	113	1100
Dieldrin	0.006	NSA	0.0399	0.269	2.69	2.4	24
Endrin	0.007	NSA	82.1	613	613	657	657

NA - Not applicable
NSA - No standard available
(a) Certified Reporting Limit used in RI
(b) Background Concentration established in RI
(c) Based on a Residential cancer risk of 1E-06 or an HQ of 1
(d) Based on a Light Industrial cancer risk of 1E-06 or an HQ of 1
(e) Based on a Light Industrial cancer risk of 1E-05 or an HQ of 1
(f) Based on a Military cancer risk of 1E-06 or an HQ of 1
(g) Based on a Military cancer risk of 1E-05 or an HQ of 1
(h) Action level for lead established at 500 ug/g

Source: References 2 and 4

Table 2-6: Preliminary Numerical Cleanup Levels for Contaminants in Soil at the ADA

Contaminant of Concern	Cleanup Level ug/g	Basis	Contaminant of Concern	Cleanup Level ug/g	Basis
Aluminum	274000	Risk-based	Zinc	54800	Risk-based
Antimony	110	Risk-based	Cyanide	5480	Risk-based
Arsenic	5.24	Background	Nitrate/nitrite	438000	Risk-based
Barium	13700	Risk-based	Trichloroethylene	58	Risk-based
Beryllium	1.86	Background	Xylenes	354000	Risk-based
Cadmium	127	Risk-based	135 TNB	1.05	Risk-based
Chromium	32.7	Background	246 TNT	1.64	Risk-based
Cobalt	15	Background	24 DNT	0.424	CRL
Copper	10100	Risk-based	26 DNT	0.085	CRL
Iron	26233	Background	HMX	1050	Risk-based
Lead	500	Risk-based	RDX	5.81	Risk-based
Manganese	15200	Risk-based	Tetryl	211	Risk-based
Mercury	81.9	Risk-based	Nitrobenzene	10.5	Risk-based
Nickel	470	Risk-based	DDD	2.66	Risk-based
Potassium	2179	Background	DDE	1.88	Risk-based
Selenium	1370	Risk-based	DDT	1.88	Risk-based
Silver	1370	Risk-based	Dieldrin	0.0399	Risk-based
Thallium	31.3	Background	Endrin	82.1	Risk-based

Notes:
- Numerical values for Risk-based Cleanup Levels are based on risk calculations presented in the RA for future residential use with residual risk of less than 1x10-6

CRL - Certified Reporting Limit

Source: Reference 4

2.3 General Response Actions

2.3.1 Description

This section describes broad categories of remedial measures, called general response actions, that could be used to achieve the remedial action objectives described in Section 2.2.4, Development of Remedial Action Goals. A particular general response action might be able to be accomplished by any of several technology types. In turn, a single technology type might encompass several more specific methodologies called process options. For example, "treatment" would be a general response action, "thermal treatment" would be a technology type, and incineration or thermal desorption would be two examples of process options.

The following general response actions considered alone or in combination could potentially achieve the remedial action objectives:

- No Action
- Institutional Controls
- Containment
- Disposal
- Clearance of UXO
- Treatment, In Situ; and/or
- Treatment, Ex Situ

The NCP requires that "No Action" be included among the general response actions evaluated in every FS [40 CFR 300.430(e)(6)]. No Action means that no response to contamination is made, activities previously initiated are abandoned, and no further active human intervention occurs. However, some natural attenuation of the chemically contaminated media (in contrast to ordnance-contaminated media) may occur over time through dilution, biological degradation (of organic contaminants), and abiotic degradation (of organic contaminants). Due to the persistence of metal contaminants, little or no natural attenuation of metal-contaminated soil is expected over time. The No Action response provides a baseline for comparison to the other remedial response actions.

Institutional controls include measures such as site access restrictions (e.g., deed restrictions and/or fencing) and land use restrictions (specifying future use such as residential, light industrial, or military). Although potential exposure can be reduced by these means, the contaminated media are not directly remediated. As with the No Action scenario, natural recovery of organic-contaminated media might occur; however, recovery of metal-contaminated media is expected to be minimal or non-existent.

Containment actions control or reduce migration of the contaminated materials into the surrounding environment. They might also isolate the contaminated media to reduce the possibility of exposure by direct contact. These actions may involve the use of physical barriers to block a contaminant migration pathway.

The clearance of UXO is a site-specific action that is to be considered for the surface and subsurface at the ADA. Specific activities to be involved include: surface clearance and subsurface surveys, and excavation of buried UXO. For the purposes of this FS, it is assumed that recovered UXO will be turned over to government personnel for on site detonation (or deactivation) and disposal.

The treatment actions may include the use of biological, physical-chemical, or thermal processes to significantly reduce the toxicity, solubility, mobility, or volume of wastes. In some cases, treatment technologies are used to change the properties of the waste so as to limit the solubility or mobility of the contaminants or to prepare the waste for further treatment. Many treatment options will generate residuals or byproducts that must be disposed of with or without further treatment. The residuals or byproducts might or might not be hazardous.

2.3.2 Estimated Areas and Volumes of Contaminated Media Requiring Remediation

In order to develop estimates of areas and volumes requiring remediation with any degree of certainty, it is necessary to examine the chemical contamination profile of each site to be remediated and compare the concentrations of contaminants of concern with the specific remedial goals presented in Table 2-6. Many of the sites at the ADA involve considerable areas and the sampling performed represented a small subset of these areas. In addition, characterization of contamination may be limited by the depth to which sampling occurred. Consequently, it is important to note that these estimates are based on a degree of uncertainty regarding the delineation of the vertical and areal extent of contamination. These uncertainties are factored into the area and volume estimates by using a 25% uncertainty factor.

Despite these uncertainties, it appears as though contamination is limited to surface, or near-surface soils. In addition, contamination does not appear to be a function of depth. This latter feature is likely due, in part, to sporadic grading activities that have occurred over the years at the ADA sites.

In addition to the development of soil volumes requiring remediation in accordance with the cleanup levels provided in Table 2-6, affected areas and volumes requiring remediation have been calculated based on selected potential remedial goals provided in Table 2-5. Specifically, additional areas and volumes have been calculated for: future use

of residential with a residual risk of 1×10^{-6}; and future use of industrial with residual risks of 1×10^{-6} and 1×10^{-5}. Because the calculated risks associated with future use of military are due only to dust inhalation, only surface contamination is considered.

To support the estimation of areas and volumes requiring remediation as described above, Table 2-7 is provided. This table provides the identification of sample locations (by site) and depths (actual depths of samples) at which particular remedial goals were exceeded in addition to identifying the specific contaminants.

Since the completion of the RI, additional soil sampling and analyses have been performed at ADA Sites 15, 17, 18, and 19. The results of these additional soil characterizations as they affect the calculation of affected areas and volumes are provided in Appendix B of this report.

Based on the information presented in Table 2-7 and the results of post-RI sampling and analyses, area and volume estimates were prepared. These estimates are presented in Table 2-8. For reference, maps illustrating the contaminated locations and area and volume calculation worksheets are provided in Appendix B.

2.4 Identification and Screening of Technology Types and Process Options

In this section, the technologies and process options associated with the general response actions discussed in Section 2.3, General Response Actions, are identified and described. These technologies and process options were subjected to a two-step screening process to eliminate inappropriate remedial options. The conduct of the screening process and its results are presented below.

The screening process was initiated with a preliminary screening to assess the response of the identified technologies and process options to technical and regulatory requirements. In this stage, those technologies and process options that were determined to be clearly inappropriate were eliminated from further consideration.

Those technologies and process options that survived the preliminary screening were then subjected to a final screening consisting of a more detailed evaluation specifically based on the following criteria:

- Effectiveness
- Implementability
- Cost

Table 2-7. Summary of Contaminated Soil Locations and Depths at ADA Sites for Different Future Use Scenarios

Site	Residential 1E-06			Light Industrial 1E-06			Light Industrial 1E-05			Military 1E-06		
	Sample No.	Depth (a) (ft)	Contaminant	Sample No.	Depth (a) (ft)	Contaminant	Sample No.	Depth (a) (ft)	Contaminant	Sample No.	Depth (a) (ft)	Contaminant
13	13-2	3 (11.5)	M, E	13-2	3 (11.5)	M, E	13-2	3 (11.5)	M			
	13-3	0 (10)	M, E	13-3	0 (10)	M, E						
15	15-1	7.5 (10)	M, E	15-1	7.5 (10)	M, E	15-1	7.5 (10)	M, E			
	15-2	1 (3)	M, E	15-3	3 (5)	M, E	15-3	3 (5)	M, E			
	15-3	3 (5)	M, E	15-4	1 (10)	M, E	15-4	1 (10)	M, E			
	15-4	2.5 (10)	M, E									
16	16-5	10 (10)	M, E	16-4	0 (10)	M, E	16-6	2.5 (10)	M, E	16-4	0 (10)	M, E
	16-10	2.5 (10)	M, E	16-5	10 (10)	M, E	16-10	2.5 (10)	M, E			
				16-6	2.5 (10)	M, E						
				16-10	2.5 (10)	M, E						
17	17-1	0 (0)	M, E	17-1	0 (0)	M	17-1	0 (0)	M	17-1	0 (0)	M
	17-4	0 (0)	M, E									
18	18-2	10 (10)	M	18-2	10 (10)	M	18-2	10 (10)	M	18-2	0 (10)	M
	18-3	5 (10)	M	18-4	7.5 (10)	[illegible]	18-4	7.5 (10)	M			
	18-4	7.5 (10)	M	18-5	10 (10)	[illegible]	18-5	10 (10)	M			
	18-5	10 (10)	M									
19	19-1	10 (10)	M	19-1	10 (10)	M	19-7	0 (10)	M	19-7	0 (10)	M
	19-5	5 (10)	M	19-5	5 (10)	M	19-8	0 (10)	M	19-8	0 (10)	M
	19-6	2.5 (10)	M	19-6	2.5 (10)	M	19-9	0 (10)	M	19-9	0 (10)	M
	19-7	0 (10)	M	19-7	0 (10)	M	19-10	0 (10)	M	19-10	0 (10)	M
	19-8	0 (10)	M	19-8	0 (10)	M						
	19-9	0 (10)	M	19-9	0 (10)	M						
	19-10	2.5 (10)	M	19-10	0 (10)	M						

Table 2-7. Summary of Contaminated Soil Locations and Depths at ADA Sites for Different Future Use Scenarios (continued)

	Residential 1E-06			Light Industrial 1E-06			Light Industrial 1E-05			Military 1E-06		
Site	Sample No.	Depth (a) (ft)	Contaminant	Sample No.	Depth (a) (ft)	Contaminant	Sample No.	Depth (a) (ft)	Contaminant	Sample No.	Depth (a) (ft)	Contaminant
31	31-1	5 (10)	M, E, P	31-1	5 (10)	M, E, P	31-1	5 (10)	E, P			
	31-6	0 (10)	M, E, P	31-6	0 (10)	M, E, P	31-6	0 (10)	E, P	31-6	0 (10)	E, P
32- I, II	32-3	0 (0)	M, E	32-1	0 (0)	M, E	32-1	0 (0)	M	32-1	0 (0)	M
	32-4	0 (0)	M, E	32-3	0 (0)	M, E	32-3	0 (0)	M	32-3	0 (0)	M
	32-6	0 (0)	M, E	32-4	0 (0)	M, E	32-4	0 (0)	M	32-4	0 (0)	M
	32-7	0 (0)	M, E	32-6	0 (0)	M, E						
	32-8	0 (0)	M, E	32-7	0 (0)	M, E						
				32-8	0 (0)	M, E						
56	56-2	1.5 (3.5)	M									
57-III	57-15	0 (10)	M	57-15	0 (10)	M	57-15	0 (10)	M			

(a) Numbers in parentheses indicate the maximum depth of the sample

Notes
Depth of "0" indicates surface contamination only
M - Metals
E - Explosives
P- Pesticides

Source: Arthur D. Little, Inc.

Table 2-8. Affected Areas and Remediation Volumes by Site and Risk Levels

	Residential 1 x 10-6			Light Industrial 1 x 10-6			Light Industrial 1 x 10-5			Military 1 x 10-6		
Site	Area sq ft	Volume cu yd	Contaminant	Area sq ft	Volume cu yd	Contaminant	Area sq ft	Volume cu yd	Contaminant	Area sq ft	Volume cu yd	Contaminant
13	15750	1750	M, N	15750	1750	M, N	7875	875	M	0	0	
15	88000	13333	M, N	66750	5000	M, N	66750	5000	M, N	0	0	
16	1800	417	M, N	3600	517	M, N	1800	167	M, N	900	17	M,N
17	439	8	M, N	244	5	M	244	5	M	244	5	M
18	22250	6366	M	16250	5255	M	16250	5255	M	16250	5255	M
19	26250	7772	M	26250	7772	M	11250	4531	M	11250	4531	M
31	3550	362	M, N	3550	362	M, N	3550	362	M,N	1420	33	M,N
32-II	17000	315	M,N	25000	463	M, N	25000	463	M,N	25000	463	M
32-I	30875	572	M, N	30875	572	M, N	0	0	M	0	0	
56	6250	347	M	0	0		0	0		0	0	
57-III	78125	1447	M	78125	1447	M	78125	1447	M	0	0	
Total - M		15932			14479			12113		27744	10254	
Total - M,N		16442			8201			5005		900	50	
Total	290289	32689		266394	23143		210844	18105		55064	10304	
Total *	**290000**	**32700**		**266000**	**23100**		**211000**	**18100**		**55100**	**10300**	

Note: Areas and volumes include uncertainty factor of 1.25

M - Metals
N- Nonvolatile Organic Compounds
*Totals rounded to three significant figures

Source: Arthur D. Little, Inc.

At this stage, greater emphasis was placed on effectiveness and implementability to identify the most promising of the technologies and process options to achieve the remedial goals. Cost was a secondary consideration. Only relative capital and operating and maintenance (O&M) costs were considered, with evaluations made largely on the basis of engineering judgement. Technologies and process options surviving the final screening are used to develop remedial alternatives that will be subjected to a detailed evaluation and analysis as described in Section 4.0, Detailed Analysis of Alternatives.

2.4.1 Identification and Screening of Technologies

The identification and screening of technologies and process options were based on a number of factors, including:

- Waste characteristics
- Site characteristics
- Technology characteristics
- Regulatory preferences

2.4.1.1 Waste Characteristics. Within the ADA, soils have been found to be contaminated with metals and, to a much lesser extent, organics (explosives and pesticides). The concentrations of organics in the soils are generally very low compared to metal concentrations.

Specific waste characteristics that could potentially influence the screening process include:

Reactivity. Military regulations and prudence dictate that technologies considered for remediation mitigate the possibility of a detonation. Reactivity studies performed for USATHAMA[22] identified that a concentration of explosives in soil of 12 percent by weight is the minimum concentration at which detonation would occur. As a conservative guideline, USATHAMA has adopted a 10 percent concentration as the minimum at which reactivity would be a concern. Concentrations of explosives in soil at the ADA are well below that concentration (an average of approximately 0.2 percent at sites where they are present with a maximum detected of about 4 percent) indicating that the contaminated soil does not present a concern on the basis of reactivity. However, reactivity will be addressed, as necessary, for those technologies that involve processes that concentrate or accumulate explosives.

Volatility. Technologies that rely solely on the volatility of the contaminants are not appropriate for the removal of contaminants (metals or organics) from soil at the ADA. In general, the contaminants are not volatile to any appreciable degree at ambient or even moderately elevated temperatures. The contaminants may volatilize at temperatures

required for incineration, but at such temperatures, volatility will not be the only mechanism involved in their removal from the soil.

Aqueous Phase Solubility. Technologies requiring removal of contaminants from soil by solubilizing them in water are not appropriate for the contaminants at the ADA. The contaminants (metals, explosives, and pesticides) are generally insoluble in water.

A summary of physical and chemical properties (including vapor pressures and solubilities) for all contaminants of concern at UMDA is provided in Appendix A of this report.

Soil Volume Requiring Remediation. The total soil volume to be remediated may affect the selection of the best remediation technology or process option. The volumes to be used in the screening and evaluation of technologies or process options were presented in Table 2-8.

2.4.1.2 Site Characteristics. Site characteristics that influence the screening and evaluation of alternatives include:

Location and Accessibility. UMDA is located in a rural setting. The ADA is located in the northwest portion of the installation and entirely enclosed by a fence. Roads are located adjacent to or within one-half mile of each site to be remediated. There are no severe space limitations imposed by structures or geophysical barriers.

Security. UMDA is fenced and guarded 24 hours a day. In addition, the ADA is itself enclosed by a guarded fence with heavily controlled access. It is expected that UMDA will retain its status as a restricted-access military installation at least through the 1990s.

Proximity to Potential Receptors. Military and civilian personnel assigned to UMDA are the only reasonable nearby receptors, at this time, because of the limited access and distance from civilian populations.

Resource Availability. Electrical service is available at the ADA. The site does not have natural gas service. Water can be supplied from the installation hydrant system. However, the substantial irrigation needs of the region combined with the semi-arid climate limit the acceptability of remedial action alternatives that would require large volumes of water. Evaporation basins have been used successfully at UMDA to dispose of nonhazardous ground water from sampling activities. Basins could be constructed in the ADA for remedial actions.

Surface Conditions. The ADA is covered by grasses and low brush. Some areas of the individual sites at the ADA may be devoid of vegetation due to past or present disposal activities.

Geology. The site geology is described in Section 1.2.2 of this report. In general, surficial deposits consist predominantly of fine- to medium-grained sands, silty sands, and some gravels. The hydraulic conductivity of the soil falls within a range of 10^{-2} to 10^{-4} cm/sec. Depth to ground water varies across the ADA. Apparent depths range from about 50 to 100 feet; fluctuations of 1 to 2 feet may be observed due to seasonal variations in precipitation.

Unexploded Ordnance. Past activities at the ADA have resulted in the presence of surface and subsurface unexploded ordnance (UXO). This feature has a significant impact on the screening and evaluation of alternatives due to the inherent safety concerns associated with future land use and treatment alternatives.

2.4.1.3 Technology Characteristics. General technology characteristics that contribute to technology screening and evaluation include:

In Situ versus Ex Situ Treatment. For soil remediation, in situ treatment provides the advantage of implementing the technology without having to excavate the soil, thereby reducing potential for exposure as well as, in some instances, reducing costs. However, in situ technologies are limited by the need to be able to perform the treatment uniformly throughout the soil and, equally important, to provide evidence of completeness and permanence of the remediation. For most in situ technologies, effectiveness is very dependent on site-specific features such as geology, hydrology, soil characteristics, and contaminant characteristics. In situ treatment may not be appropriate for ADA soils that contain UXO.

On-site versus Off-site Treatment. The NCP specifies a preference for on-site remedies as opposed to off-site remedies. On-site remediation should eliminate the need to apply for and obtain local, state, and federal permits, although it does not preclude meeting the substantive requirements of the permit regulations. Other advantages of on-site remediation include:

- The waste generator retains greater control of the waste and residues.
- Costs of transportation are minimized.
- Potential for spread of contamination and exposure are reduced.

Costs of on-site treatment may be less than off-site treatment, particularly if there is a sufficient waste volume. In cases where the volume of waste to be treated is small,

on-site treatment costs may be higher than off-site because of the costs required to mobilize a treatment system on site.

Off-site treatment and disposal relieves the waste generator of the responsibility for meeting the substantive requirements for waste treatment and disposal facilities provided a properly permitted facility is chosen. However, the generator retains future liability for those wastes treated off site. This liability extends to treatment residuals, although the generator has little control over the management or disposition of the residuals.

An additional disadvantage of off-site treatment over on-site treatment is the increase in short-term risks due to the increased potential for public exposure and environmental damage in the event of spills or mishaps during transportation of the waste off site.

2.4.2 Evaluation of Technologies and Selection of Representative Technologies

The general response actions introduced in Section 2.2, Remedial Action Objectives, and potentially applicable technologies and process options are presented in Figure 2-1. The results of the preliminary screening are shown in the figure by shading those technologies and process options that are clearly not applicable to remediation of the ADA soils. The rationale supporting the elimination of these technologies and process options is summarized in the column on the right.

Technologies and process options were initially screened by assessing whether or not they were conceptually viable with respect to technical capabilities and the screening criteria presented in Section 2.4.1, Identification and Screening of Technologies. A brief discussion of the important parameters and rationale behind particular screening decisions is provided below.

It is important to note that the technologies and process options surviving the preliminary screening (as well as the final screening) will be incorporated into remedial alternatives that will then be subjected to a detailed analysis. These remedial alternatives may consist of a single technology or process option or may include a series of the retained options.

2.4.2.1 Preliminary Screening.

No Action. The No Action alternative does not reduce human exposure or contaminant toxicity, mobility, or volume. However, as required by the NCP, it will be carried through subsequent screening and analysis as a viable option where appropriate to provide a baseline reference point for review and comparison of various alternatives.

This alternative is independent of the contaminant/soil matrix considered.

Figure 2-1: Preliminary Screening of Technologies and Process Options for Contaminated Soil

General Response Action	Remedial Technology	Process Option	Description	Screening Comments
No Action	None	None	No Action	Required for consideration by the National Contingency Plan
Institutional	Access Restriction	Deed Restriction	Restrict site use through legally binding requirements on property	Potentially applicable
		Fencing	Put fence around site	Existing
	Land Use Restriction	Residential	Property use will be restricted to residential with no agricultural use	Potentially applicable
		Light Industrial	Property use will be restricted to light industrial	Potentially applicable
		Military	Property use will be restricted to military	Potentially applicable
UXO Clearance	Survey and Clearance	Surface Clearance	Remove visible ordnance from soil surface	Potentially applicable
		Clearance to 1 foot	Remove visible and buried ordnance to a depth of 1 foot	Potentially applicable
		Clearance to 5 feet	Remove visible and buried ordnance to a depth of 5 feet	Potentially applicable
		Clearance to 20 feet	Remove visible and buried ordnance to a depth of 20 feet	Potentially applicable
Containment	Capping	Engineered Cap	Install single or multilayered cap of materials such as clay, asphalt, concrete, and/or synthetic membrane	Potentially applicable
	Surface Control	Clean Soil Cover	Install layer of clean soil over contaminated area	Potentially applicable
		Vegetation	Plant vegetation over contaminated area	Potentially applicable

Potentially applicable technology

Eliminated from further consideration

Figure 2-1: Preliminary Screening of Technologies and Process Options for Contaminated Soil (continued)

General Response Action	Remedial Technology	Process Option	Description	Screening Comments
On-Site Disposal	Landfilling	Existing Landfill	Dispose of contaminated soil and/or treatment residues in existing landfill	Potentially applicable
		New Landfill	Dispose of contaminated soil and/or treatment residues in new on-site landfill	Potentially applicable
Treatment, In Situ	Biological	Aerobic	Destruction of contaminants by aerobic microorganisms	Not applicable due to metal contaminants
		Anaerobic	Destruction of contaminants by anaerobic microorganisms	Not applicable to metal contaminants
	Physical-Chemical	Soil Washing	Leach contaminant from soil with a water and detergent solution	Not applicable to metal contaminants
		Solidification/Stabilization	Immobilize contaminants using cement, pozzolans, and/or setting agents	Not applicable due to lack of proof of effectiveness or permanence of remedy
		Vacuum Extraction	Place soil under vacuum to enhance organic volatilization	Not applicable to nonvolatile contaminants
	Thermal	Radio Frequency Heating	Volatilize contaminants by heating the soil with radio frequency waves	Not applicable to nonvolatile contaminants
		Thermal Stripping	Volatilize contaminants by heating the soil	Not applicable to nonvolatile contaminants
		Vitrification	Encapsulate contaminants by glassifying soil at high temperatures	Not applicable due to lack of proof of effectiveness or permanence of remedy

☐ Potentially applicable technology

▒ Eliminated from further consideration

Figure 2-1: Preliminary Screening of Technologies and Process Options for Contaminated Soil (continued)

General Response Action	Remedial Technology	Process Option	Description	Screening Comments
Treatment, Ex Situ	Biological	Slurry-Phase Treatment	Degrade contaminants in a slurry reactor	Not applicable to soil contaminated primarily with metals
		Composting	Degrade contaminants by processing soil with amendments, fertilizers, and water	Not applicable to soil contaminated primarily with metals
	Physical-Chemical	Solidification/Stabilization	Immobilize contaminants in soil using cement, pozzolans, and/or setting agents	Potentially applicable
		Soil Washing	Remove contaminants from soil by chemical and/or physical means	Potentially applicable to reduce soil volume requiring treatment
	Thermal	Glassification	Encapsulate contaminants by glassifying soil at high temperatures	Potentially applicable
		Incineration	Decompose and volatilize contaminants at high temperatures	Potentially applicable
		Thermal Stripping	Volatilize contaminants from soil by low temperature thermal processing	Not applicable to nonvolatile contaminants
	Off-Site	Treatment or Disposal	Treat or dispose of contaminated soil at a RCRA-approved facility	Potentially applicable

Potentially applicable technology (unshaded)

Eliminated from further consideration (shaded)

Institutional Controls. The placement of institutional controls such as access restrictions and/or land use restrictions on the future use of the ADA is a means of minimizing or preventing human exposure to contaminants. However, such restrictions do not reduce the toxicity, mobility, or volume of contaminants.

The use of access restrictions such as the imposition of deed restrictions or fencing will limit future use possibilities for the site. Despite this limitation, there are two issues that impact the decision to carry access restrictions to the next stage of evaluation. These are:

- The absence of future use plans for UMDA in general and the ADA specifically
- The presence of UXO at the ADA is likely to have a significant impact on future use considerations

Land use restrictions constitute an additional aspect to institutional controls. The options under consideration include:

- Restriction of future property use to residential only with no agricultural use permitted
- Restriction of future property use to light industrial only
- Restriction of future property use to military

Because of the uncertainties associated with future use scenarios at this time, as well as the potential impact of UXO on future use, all institutional control options will be carried over into the next phase of the evaluation.

The use of institutional controls is independent of the contaminant/soil matrix considered.

UXO Clearance. Some clearance of UXO from the ADA will be needed to conduct remedial actions and also if more intensive land use than exists now is desired. UXO clearance is technically feasible and has been demonstrated effective[25]. UXO clearance levels considered for the ADA include surface clearance and subsurface clearance at depths of 1, 5, and 20 feet. Specific clearance requirements are tied closely to any institutional controls that may be applied at the ADA regarding future use and, therefore, all clearance options are retained for further consideration.

Containment. Waste containment technologies are generally intended to minimize exposure to contaminated soil and/or to reduce the mobility of contaminants to prevent their migration. The toxicity or volume of the contaminants is not reduced. Containment options considered include the use of surface controls such as a clean soil cover and/or vegetation as well as capping the site with an engineered cap.

Surface controls are relatively inexpensive and low-technology approaches to containment Such controls include: applying a clean soil layer over the contaminated soil and/or planting vegetation over the contaminated area. Due to the arid and exposed conditions at UMDA, a clean soil layer alone would provide an expedient, but short-term means of containment due to wind erosion. For this reason, use of a clean soil cover alone is eliminated from further consideration. Covering the clean soil with vegetation would decrease the potential for erosion due to wind by increasing the stability of the surface environment. A combination of clean soil cover and revegetation is retained for further consideration as a potentially effective means of controlling the wind dispersion of contaminants.

In many cases, vegetation alone would adequately decrease the potential for wind dispersion of surface contaminants. However, the native vegetation of UMDA is sparse and not well-suited for erosion control. For this reason, vegetation as the sole means of surface control is eliminated from further consideration.

A higher-technology approach to containment is offered by the use of engineered caps over the contaminated soils. Engineered caps may be constructed from a variety of materials, including asphalt, concrete, clays, sands, and soils. These caps may consist of a single layer or may be composed of multiple layers. Single layer caps will generally require continuous and long-term monitoring to ensure that their integrity is retained. Multiple layer caps are more desirable for uses requiring long-term protection of human health and the environment. For the purposes of longevity of cover and insurance of long-term maximum protection, a multiple layer cap consisting of a clay layer covered by clean soil will be retained for further evaluation.

On-Site Disposal. The use of on-site disposal of contaminated soil and/or treatment residues may be accomplished using the existing active landfill or, alternatively, by constructing a new engineered landfill on site for the specific purpose of disposal of these materials. The toxicity or volume of the contaminants is not reduced by implementation of these options; however, they may allow for greater control of the potential spread of contamination than if the contaminated soil were to be left in place.

Consideration of the use of on site disposal for the contaminated soil is impacted by LDR prohibiting the disposal of soil exhibiting the characteristic of toxicity. As described in Section 2.2.2.3.1, Soil as Hazardous Waste, ADA soils containing the metals cadmium and lead potentially exhibit the toxicity characteristic and, as such, land disposal of these contaminated soils (without treatment) may be prohibited. A review of contamination data developed in the RI indicates that the toxicity characteristic may be exhibited by over half of the total contaminated soil volume at the ADA due to the presence of lead. The use of on-site disposal for contaminated soils would be limited to those soils that do not

exhibit any hazardous characteristic and would require extensive testing to ensure that the soils to be placed on site are not hazardous. On-site disposal in either the existing active landfill or in a new engineered landfill is retained for consideration for the disposal of proven nonhazardous soils only.

If it can be shown that the contaminated soil that exhibits the hazardous characteristic can be treated so that it no longer exhibits that characteristic, then that treated material is no longer subject to LDR and can be landfilled. Use of on-site landfills (either the existing landfill or a new landfill) for the disposal of residuals resulting from the treatment of contaminated soil is retained for further consideration because of the technical feasibility of on-site disposal and its potential to reduce exposure and migration of contamination.

In Situ Treatment. In situ options considered include treatment by biological, physical-chemical, and thermal methods.

Biological In Situ Treatment. The use of aerobic or anaerobic microorganisms to degrade contaminants in soil is a potentially effective method for reducing the toxicity and mobility of organic compounds in soil. However, the use of microorganisms in situ has not been demonstrated to affect the mobility or toxicity of metals. Another in situ or ex situ method may then be needed to address the metals. Since the contaminated soils at the ADA contain metals, this option has been dropped from further consideration for all three contaminant/soil matrices.

Physical-Chemical In Situ Treatment. Physical-chemical treatment techniques that may be employed in situ include:

- Soil washing, in which contaminants are leached from the soil with a water and detergent solution. This technique has been proven to a greater extent with soil that has been excavated. Because the contamination at this site is relatively shallow (less than 15 feet below the surface) and relatively easy to excavate, there is no particular advantage to the use of the processes in situ. In situ applications of soil washing are therefore eliminated from further consideration.

- Solidification/stabilization, involving the mixing of specialized additives or reagents with contaminated soil to physically or chemically reduce the solubility or mobility of contaminants in the soil. Stabilization typically refers to techniques that chemically modify the contaminant to form a less soluble, mobile, or toxic form without necessarily changing the physical characteristics of the waste. Solidification refers to a technique for changing the physical form of the waste to produce a solid structure in which the contaminant is mechanically trapped. Many stabilization and solidification processes overlap and therefore are often described

as one technology. Although these processes have reportedly been demonstrated with a variety of contaminants (primarily metals), their long-term effectiveness and permanence is unknown. The technology has been proven to a greater extent with soil that has been excavated. Because the contamination at this site is relatively shallow (less than 15 feet below the surface), there is no particular advantage to the use of the processes in situ. In situ applications of solidification/stabilization are therefore eliminated from further consideration.

- Vacuum extraction, in which the soil is placed under vacuum to enhance the volatilization of contaminants from the soil. Since the contaminants of concern at the ADA are nonvolatile, this alternative is dropped from further consideration for all three contaminant/soil matrices.

Thermal In Situ Treatment. Two thermal techniques for in situ soil remediation are radio frequency heating and thermal stripping. Both of these techniques involve heating soil, thereby enhancing volatilization of contaminants for their removal from the soil. Since the success of these methods depends on the volatilization of the contaminants, they are clearly not appropriate for the nonvolatile contaminants at the ADA. Thermal in situ treatment relying on the volatilization of contaminants is therefore eliminated from further consideration for all three contaminant/soil matrices.

A third thermal technique that can be employed in situ is vitrification, a method whereby contaminants are immobilized in place through encapsulation in glassified soil. This technique typically involves the addition of chemicals to contaminated soil followed by the application of electrical energy to produce a solidified (glassified) soil. This technology has not been successfully demonstrated on a large scale and has not been demonstrated on any scale with explosives. In addition, the success of in situ vitrification relies on the assurance that the vitrified mass is continuous throughout the contaminated site, thereby eliminating the potential for future leaching or movement of contaminants from the site. This ability has not yet been demonstrated. Because of insufficient demonstration of the effectiveness of vitrification as well as uncertainties about its permanence, this technology is eliminated from further consideration for all contaminant/soil matrices at the ADA.

Ex Situ Treatment. In ex situ treatment, contaminated soil is excavated from the site and subjected to treatment on site or off site. Options for treatment include processes employing biological, physical-chemical, or thermal methods.

Biological Ex Situ Treatment. Potential technologies employing biological processes to treat contaminated soil ex situ include slurry-phase treatment and composting.

- Slurry-phase treatment involves diluting the contaminated soil with water and feeding the resulting slurry to a system containing bacteria. Although slurry phase treatment was considered conceptually viable in a 1990 evaluation (for organic contamination), effectiveness has not yet been demonstrated[26]. This technology is therefore eliminated from further consideration for contaminated soil remediation at the ADA.

- Composting is an innovative method for the treatment of soils contaminated with organic compounds, including explosives. Composting is commonly used for treating sewage sludge, municipal solid wastes, and yard wastes. Recently it has been examined for use in remedial actions involving the treatment of contaminated soil. In order to achieve composting conditions, contaminated soils must be altered to produce a compostable matrix. Usually this is accomplished by adding an amendment mixture to the contaminated soil. This amendment mixture typically consists of a bulking agent to improve the physical characteristics of the soil and a carbon and nitrogen source for ensuring the sustenance of active microbial populations. The reliance on amendments is a potential disadvantage to composting due to the increase in volume (as much as 200%) of the contaminated media.

  Composting has been demonstrated for site-specific applications involving the treatment of soil contaminated with explosives. Treatability studies have shown that it can effectively reduce contaminant concentrations and soil toxicity by greater than 90 percent [27,28].

  The effect of composting on metal-contaminated soil has not been determined. Although it is suspected that composting may result in immobilization of the metals, it has not been demonstrated or proven on any scale[29]. There is the potential that the levels of metals in the ADA soils may prove toxic to biological activity. All of the identified contaminated soil at the ADA contains metals at significantly higher concentrations and greater frequency than explosives or other organics. The use of composting as a pretreatment to remove organic contaminants prior to subsequent treatment to remove metals is not practical due to the significant increase in volume resulting from the addition of soil amendments. For these reasons, the feasibility of using composting to treat these soils is questionable and thus will not be considered further in this analysis.

Physical-Chemical Ex Situ Treatment. Physical-chemical techniques that can be employed to treat excavated soil include solidification/stabilization and soil washing.

- Solidification/stabilization involves the mixing of specialized additives or reagents with contaminated soil to physically or chemically reduce the solubility or mobility of contaminants in the soil. Stabilization typically refers to techniques that chemically modify the contaminant to form a less soluble, mobile, or toxic form without necessarily changing the physical characteristics of the waste. Solidification refers to a technique for changing the physical form of the waste to produce a solid structure in which the contaminant is mechanically trapped. Many stabilization and solidification processes overlap and therefore are often described as one technology. These techniques have been demonstrated to be implementable to treat soil contaminated with metals and therefore have potential application as a remedial alternative for soils at the ADA. The effect of solidification/stabilization on organics has not been as well demonstrated. In some cases, organics may even negatively impact the quality of the treated product. Treatability studies would be required to determine the effect of any organics on the treated matrix as well as to demonstrate the feasibility of the process on ADA soils in general and develop optimum operating parameters. Despite the uncertainties with respect to organic contamination, it should be noted that the level and frequency of organic contamination at the ADA is very low compared to metal contamination. Because of the potential for immobilization of metal (and perhaps organic) contaminants at the ADA, solidification/stabilization is retained in this evaluation for further consideration.

- Soil washing involves the removal of contaminants from soil by chemical and/or physical means. It is typically employed as one of a series of unit operations. Soil washing results in the transfer of contaminants from one medium (soil) to another (liquid), thereby requiring additional treatment. Specific processes involved in soil washing include:

  - Physical separation of contaminated particles by washing with water, agitation, and particle classification. When used on contaminated soil, this process makes use of the tendency of contaminants to concentrate in the finer particles (or fines) of soil leaving the larger particles relatively contaminant-free. Ideally, separation of the two ranges of particle sizes then allows for a significant reduction in soil volume to be treated.

  - Solvent extraction using an appropriate solvent to solubilize the contaminants, which are then removed from the soil with the solvent.

  - Acid extraction making use of the solubility of metals in acid to remove them from soil. An acidic aqueous solution is added to the excavated soil, the metals are dissolved into the solution, and the metal-laden solution is separated from the soil and subjected to further treatment.

The soil washing processes described above may be used alone or in combination depending on the contaminant(s) to be removed from soil.

Soil washing using water to physically remove contaminants from soil has been demonstrated effective in specific applications [30,31]. Application of the technology has the potential to substantially reduce the volume of contaminated soil requiring further treatment or disposal. The soil washing technology is reportedly moderately to marginally effective for the removal of pesticides from soil. In addition, bench-scale studies conducted by USATHAMA indicate that removal efficiencies of explosive compounds are generally poor [32].

Solvent extraction has been demonstrated on a laboratory scale to be an effective means of removing explosives and pesticides contaminants from soil[33,34]. Solvent extraction is not applicable to metals in soil. A study conducted by USATHAMA used acetone to remove explosives from soil, since all of the explosives of interest were either soluble or easily dispersed in acetone at room temperature[32]. Initial concentrations of explosives in the soil ranged from 1,200 µg/g to 420,000 µg/g. Final concentrations were 6 to 17 µg/g, for an extraction efficiency of greater than 99.5 percent.

The limitations of solvent extraction arise upon consideration of the fate of the extract. In the study referenced above, the acetone was recovered by boiling off the liquid, leaving a small amount of acetone with the explosives to maintain them in a wet state and reduce the potential for detonation. While this reduces the volume of contaminated media, it is not a final treatment. The study concluded by indicating that the acetone/explosives mixture could then be incinerated. However, the production of a concentrated explosives moisture, particularly entrained in a flammable solvent, is generally unacceptable because of the stringent requirements imposed on facilities that process detonatable concentrations. In addition, it is unlikely that a commercial incinerator would be willing to accept a potentially explosive mixture.

Acid extraction has been used in the metallurgical industry for the extraction of metals from various media to allow for their recovery [35]. The major problem with this technology is the generation of large quantities of acid waters contaminated with metal compounds. There is no apparent application of acid extraction for the removal of explosives or pesticides.

Both solvent and acid extraction can be complex procedures employing a number of unit processes. They rely on the transfer of contaminants from one medium (soil) to

another (solvent or acid) thereby generating another waste stream requiring treatment. In addition, safety considerations associated with the storage of large quantities of acids and solvents (such as acetone) required for the processes are significant.

Soil washing using aqueous solutions to physically separate contaminants and fines from soil is retained for further evaluation due to its potential to reduce the volume of contaminated soil requiring further treatment or disposal. Solvent and acid extraction are eliminated from further consideration for a number of reasons including their reliance on large volumes of acids and solvents and the generation of acid and solvent waste streams that require subsequent treatment.

Thermal Ex Situ Treatment. Alternatives considered for the thermal treatment of excavated soil include glassification, incineration, and thermal stripping.

- Glassification makes use of well-established technology for the melting of glass. Glassification involves high temperature (typically 2200°F) treatment of contaminated solids for the purpose of destroying organic contaminants and immobilizing metals (and most other inorganics) contaminants in a glass residual product form. Organic components of wastes are thermally oxidized. Offgases are vented through a scrubber. Ash containing inorganic components is entrapped in the glass. The technology has been shown to be effective with a variety of organic compounds and metals[36]. Glassification has not been demonstrated for use with explosives; however, extrapolation of results of incineration of explosive-contaminated soil at temperatures of 1500 to 1800°F indicate that explosives would most likely be successfully oxidized at glassification temperatures [37]. Glassification is retained for further consideration based on its potential to successfully treat all contaminant/soil matrices.

- Incineration involves the oxidation of organic compounds at high temperatures. Incineration has been widely demonstrated as an effective means of remediating organic-contaminated soils including explosives and pesticides. Metals in the incinerator feed may either be contained in the incinerator offgas and subsequently separated from the offgas in air pollution control equipment or may be retained in the incinerator ash residue. Because of the demonstrated applicability of incineration for soil containing organic contaminants, it is retained for further evaluation.

- Thermal stripping involves heating soil at low temperatures thereby enhancing volatilization of contaminants for their removal from the soil. Since the success of thermal stripping depends on the volatilization of the contaminants at low

temperatures, it is clearly not appropriate for the nonvolatile contaminants at the ADA. Thermal stripping is therefore eliminated from further consideration.

Off-Site Treatment and/or Disposal. Although the NCP specifies a preference for on-site remedies, there are certain circumstances in which off-site treatment and/or disposal may be preferable; particularly for smaller waste volumes. The potential for some of the ADA soils to exhibit the toxicity characteristic due to the presence of lead (and cadmium), would require that implementation of this option involve the segregation of soils according to their toxicity characteristic. Soil exhibiting the toxicity characteristic would require treatment prior to disposal. Other soils could be disposed of as non-hazardous wastes.

Because of the potential for off-site treatment and/or disposal to be easily implemented and cost effective, this alternative is retained for further consideration for the contaminated soils at the ADA.

2.4.2.2 Final Screening of Technologies. General response actions, technologies and process options remaining after the final screening are presented in Figure 2-2. These technologies and process options have been evaluated in greater detail below according to the criteria of effectiveness, implementability, and cost. Brief descriptions of each of these criteria are presented below.

The effectiveness of the process options was evaluated based on:

- The potential effectiveness of the process option in handling the estimated areas or volumes of media and meeting the remedial action objectives
- The potential impacts to human health and the environment during the construction and implementation phase
- The degree to which the process is proven and reliable with respect to the contaminants and conditions at the site

The implementability of the process option encompasses both the technical and administrative feasibility of implementing the option. Technical implementability was the major criterion used for screening the process options in the preliminary screening to eliminate those that were clearly not applicable to the contaminants or the contaminated media. This final screening places greater emphasis on the institutional aspects of implementability, including the ability to obtain necessary permits for off-site actions; the availability of treatment, storage, and disposal services; and the availability of skilled workers to implement the technology.

Figure 2-2: Final Screening of Technologies and Process Options for Contaminated Soil

General Response Action	Remedial Technology	Process Option	Description	Screening Comments
No Action	None	None	No Action	Required for consideration by the National Contingency Plan
Institutional	Access Restriction	Deed Restriction	Restrict site use through legally binding requirements on property	Potentially applicable
		Fencing	Put fence around site	Existing
	Land Use Restriction	Residential	Property use will be restricted to residential with no agricultural use	Potentially applicable
		Light Industrial	Property use will be restricted to light industrial	Potentially applicable
		Military	Property use will be restricted to military	Potentially applicable
UXO Clearance	Survey and Clearance	Surface Clearance	Remove visible ordnance from soil surface	Potentially applicable
		Clearance to 1 foot	Remove visible and buried ordnance to a depth of 1 foot	Potentially applicable
		Clearance to 5 feet	Remove visible and buried ordnance to a depth of 5 feet	Potentially applicable
		Clearance to 20 feet	Remove visible and buried ordnance to a depth of 20 feet	Potentially applicable
Containment	Capping	Engineered Cap	Install single or multilayered cap of materials such as clay, asphalt, concrete, and/or synthetic membrane	Potentially applicable
	Surface Control	Clean Soil Cover	Install layer of clean soil over contaminated area	Potentially applicable
		Vegetation	Plant vegetation over contaminated area	Potentially applicable

Potentially applicable technology

Eliminated from further consideration

Figure 2-2: Final Screening of Technologies and Process Options for Contaminated Soil (continued)

General Response Action	Remedial Technology	Process Option	Description	Screening Comments
On-Site Disposal	Landfilling	Existing Landfill	Dispose of contaminated soil and/or treatment residues in existing landfill	Potentially applicable
		New Landfill	Dispose of contaminated soil and/or treatment residues in new on-site landfill	Potentially applicable
Treatment, Ex Situ	Physical-Chemical	Solidification/Stabilization	Immobilize contaminants in soil using cement, pozzolans, and/or setting agents	Potentially applicable
		Soil Washing	Physically concentrate contaminants by water washing and particle classification	Potentially applicable
	Thermal	Glassification	Encapsulate contaminants by glassifying soil at high temperatures	Not applicable due to high capital cost and low soil volume
		Incineration	Decompose and volatilize contaminants at high temperatures	Potentially applicable
	Off-Site	Treatment or Disposal	Treat or dispose of contaminated soil at a RCRA-approved facility	Potentially applicable

☐ Potentially applicable technology

▒ Eliminated from further consideration

The cost evaluation plays a limited role in the screening of process options. The costs that are developed are relative in nature and not detailed. These costs are usually developed based on engineering judgment, and each process is evaluated as to whether costs are high, medium, or low with respect to the other process options.

2.4.2.2.1 No Action. The No Action response action involves no technology, requires no implementation, is not effective in reducing toxicity, mobility, or volume of the waste, and incurs no direct cost. The presence of metal contaminants in the soil is expected to be persistent; little or no natural recovery will occur. Some natural degradation of organics might occur, however the rate of recovery is expected to be slow. Since the metals are by far the predominant contaminants at the ADA, the natural degradation of the organic contaminants will have little effect on the risks and hazards associated with the site. The No Action alternative is included as a requirement of the NCP and provides a baseline for comparison with the other technologies.

2.4.2.2.2 Institutional Controls. Access restrictions and land use restrictions have been carried forward to this stage of screening.

- Effectiveness. Although institutional controls alone provide a certain degree of effectiveness with respect to protecting human health by reducing the potential for exposure, they do nothing to reduce the toxicity, mobility, or volume of contaminants; therefore, they offer little improvement in protecting the environment over the long term. The imposition of these alternatives may limit future use possibilities for the site.

- Implementability. Institutional controls such as access restrictions and land use restrictions are easily implemented. The site is currently subjected to access restrictions and control.

- Cost. Despite the fact that the institutional controls themselves will be of minimal cost to implement, there will be costs incurred with the long-term maintenance of the controls as well as loss of the cost benefit possibly resulting with the sale of the site by the Army.

- Summary. Institutional controls alone will not satisfy the statutory preferences for remedies that "utilize permanent solutions." However, due to the presence of UXO at the ADA, the application of institutional controls will be required unless complete surface and subsurface clearance of UXO is conducted. However, the cost of such complete clearance may be prohibitive, thereby requiring the implementation of some degree of institutional control to provide for adequate protection of human health and environment. The use of institutional controls at the ADA is therefore retained for

further consideration, with the acknowledgement that the requirements for control may be dictated by the feasibility and cost of UXO clearance.

2.4.2.2.3 UXO Clearance. This phase of the screening will consider surface clearance of UXO as well as subsurface clearance to various depths (1 foot, 5 feet, and 20 feet). It is recognized that for any intended future use of the ADA (residential, light industrial, or military) that is different from the current use, some degree of clearance will be required. Clearance of metallic items from the surface (including UXO) is performed by visual inspection of the entire surface. The first phase of subsurface clearance involves a subsurface survey, a survey usually conducted with hand-held magnetometers (metal detectors) passed over the surface to detect subsurface items. When a subsurface item is located, it is excavated by hand or flagged for excavation after the survey is completed. Complete clearance (at depths greater than 10 feet, for example) must be performed by a combination of survey and complete excavation.

- Effectiveness. The effectiveness of UXO clearance has been proven. Because it is based on visual inspection, surface clearance provides the best degree of certainty of complete effectiveness. Subsurface clearance is complicated by the need for subsurface detection and therefore the certainty of complete effectiveness is reduced. Clearance to depths as great as 20 feet provides an effective means of UXO removal due to the complete excavation of the subsurface soil and separation of metallic items including UXO from the soil.

- Implementability. Clearance of UXO from the surface and to depths of 5 feet is relatively easily implemented. Clearance is labor-intensive and special precautions and training are necessary to ensure that it can be performed safely. For this reason, there are a number of firms that specialize in ordnance detection, removal, and destruction. Deep subsurface clearance (to 20 feet) involves excavation, which itself is easily implemented; however, excavation of the entire 1,750 acres of the ADA to a depth of 20 feet for the removal of UXO can not be considered easily implemented.

- Cost. Costs for UXO clearance are extremely variable depending on site conditions and the surface and subsurface density of metallic items (including UXO). Reported costs cover a wide range from vendor to vendor. Based on figures and factors provided by UXO clearance vendors, estimated costs have been calculated. Surface clearance costs are estimated at approximately $500 per acre. Costs for subsurface clearance to 1 foot and 5 feet are estimated at $3,000 per acre and $6,300 per acre, respectively. The costs of clearance to 20 feet across the entire ADA would be prohibitive at approximately $500,000 per acre[38].

- Summary. Some degree of clearance of UXO from the ADA will be required by Army regulation for any intended future use (including any soil excavation necessary for remediation) that differs from current use. The degree to which UXO are cleared will dictate requirements for land use or access restrictions. Clearance of UXO to a depth of 5 feet is feasible although costly. UXO clearance achieves part of the remedial objectives for the ADA. Complete clearance of UXO to a depth of 20 feet across the entire ADA is prohibitively expensive. For this reason, clearance to that depth should be considered only for selected sites if there is the potential for construction at those sites and appropriate land use and access restrictions should be applied elsewhere. Clearance of UXO from the surface and to depths of 5 feet for the entire ADA area is retained for further analysis. In addition, UXO clearance will be considered when necessary to allow for remedial actions involving excavation or handling of soil. Because of the costs associated with clearance to 20 feet, this option is retained for reference only.

2.4.2.2.4 Containment - Engineered Cap. Covering areas of contamination using an engineered cap is a technically feasible remedial option under the containment general response action. An engineered cap employed at the ADA would consist of a layer of clay covered by a layer of soil which would allow for revegetation to provide an additional level of surface stability and protection.

- Effectiveness. Capping is effective at limiting infiltration due to rainfall, providing a barrier that minimizes the potential for contact and exposure, and providing stability to the contaminated surface to limit the potential for wind dispersion of contaminants. Use of a multiple layer cap such as a clay/soil cap provides long-term assurance that the contaminated surface is stable and contained. Capping does not decrease the toxicity or volume of the contaminants.

- Implementability. From a technical standpoint, capping could be easily implemented at the areas of contamination. Equipment required for capping is readily available. The use of a cap would require maintenance and monitoring to ensure long-term integrity of the cap. Land use restrictions would be required.

- Cost. The cost to install an engineered cap using layers of clay and soil and planting vegetation would cost approximately $0.60 per square foot of area to be covered.

- Summary. The use of an engineered cap with vegetation would provide adequate protection of human health and the environment provided that the cap is maintained and monitored over the long term and some degree of future land use restrictions are applied. The cost of installing such a cap would not be prohibitive. A cap, however, does not provide for the reduction of volume of contaminated materials or

does not reduce the toxicity of the contaminants. Given the possibility that future land use restrictions will be applied at the ADA, the use of an engineered cap with vegetation is retained for further analysis.

2.4.2.2.5 Containment - Soil Cover/Vegetation. Covering areas of contamination with a layer of clean soil and vegetation is a second feasible containment option. It is assumed that suitable soil cover material would be obtained from uncontaminated areas at UMDA.

- Effectiveness. A soil cover is less effective than an engineered cap at limiting infiltration. However, since potential evapotranspiration rates in the region (32 inches per year) exceed precipitation rates (8 to 9 inches per year), a cover of clean soil would possibly reduce the amount of precipitation reaching underlying contaminated soil. A clean soil cover would also reduce the potential for direct contact with contaminated soil, both by humans and by the root systems of plants. The effectiveness of the soil cover in stabilizing the contaminated surface and preventing wind dispersion of contaminants would be enhanced by the use of vegetation. The use of a soil cover with vegetation would not reduce the toxicity or volume of contaminants.

- Implementability. Placing a soil cover over areas of contamination would be relatively simple. There are several areas of undisturbed, uncontaminated soil on the UMDA installation from which materials could be obtained. Equipment used to install the soil cover is standard and readily available. As with an engineered cap, the use of a soil cover would require maintenance and monitoring to ensure long-term integrity of the cover. Land use restrictions would be required.

- Cost. Installation of a soil cover and vegetation would cost approximately $ 0.20 per square foot of area to be covered.

- Summary. The use of a soil cover with vegetation would provide a certain degree of protection of human health and the environment provided that the cover is maintained and monitored over the long term and future land use restrictions are applied. The cost of installing such a cover would be low. A soil cover, however, does not provide for the reduction of volume of contaminated materials or does not reduce the toxicity of the contaminants. Given the possibility that future land use restrictions will be applied at the ADA, the use of a soil cover with vegetation is retained for further analysis.

2.4.2.2.6 On-Site Disposal. On-site disposal options to be considered in this phase of the screening include the disposal of nonhazardous contaminated soil and/or

nonhazardous solid treatment residuals. Disposal would be in either the existing UMDA active landfill or in a new engineered landfill to be constructed on site.

- Effectiveness. The primary benefit of relocation of the nonhazardous contaminated soils to an on-site landfill would be the increased control over the soils to minimize the potential for exposure and release to the environment. Landfilling of the contaminated soils that exhibit hazardous characteristics would not be possible without treatment to eliminate the hazardous characteristic. Once it is proven that the hazardous soils are rendered nonhazardous, then landfilling the treatment residuals provides an effective means of controlling exposure to and release of the residuals.

- Implementability. Disposal of nonhazardous materials in the on-site active landfill is easily implemented. Disposal of soil that is hazardous is complicated by the need to treat the soil prior to disposal.

- Cost. On-site disposal by utilizing the active landfill is a relatively low cost alternative with costs reflecting the excavation, hauling, dumping, and covering of the nonhazardous material is estimated at approximately $7 per cubic yard. This cost includes only the disposal costs; it does not include soil treatment costs which are considered in treatment-specific options or final closure costs, in accordance with the requirements of its permit and ODEQ solid waste regulations and guidance, which are included in the active landfill closure.

- Summary. The on-site disposal of contaminated soils and/or treatment residues will be subject to regulatory and Army approval. In general, however, on-site disposal is a feasible and potentially low cost option for disposition of the contaminated soils and/or treatment residues at the ADA. Because of the feasibility and potential low cost of on-site disposal, this option will be retained for further analysis.

2.4.2.2.7 Ex Situ Treatment-Solidification/Stabilization. Technologies and process options falling under solidification/stabilization response action are those that limit the solubility or mobility of contaminants within the soil matrix, with or without changing the physical characteristics of the matrix. They include stabilization, solidification/stabilization, and sorbent solidification. Solidification alone generally implies that the matrix is transformed into a solid monolith for the primary purpose of structural integrity. Stabilization generally implies that contaminants within the matrix become physically or chemically bound.

- Effectiveness. Solidification/stabilization would be accomplished by mixing the soil with various materials such as portland cement, certain pozzolans, silicates, thermoplastics, and/or bitumens to form a solid matrix that incorporates the

combinations of contaminants. The contaminants might or might not be chemically bound to constituents within the matrix. Site-specific treatability studies have not been performed, so the chemistry and the effective reduction in contaminant mobility cannot be evaluated. Solidification/stabilization would not reduce the toxicity or volume of the waste.

- Implementability. Solidification/stabilization may be relatively easily implemented. There are a number of vendors of turnkey systems for on-site solidification/stabilization. Equipment used is typically mobile and easily mobilized.

- Cost. The cost of solidification/stabilization varies greatly with the type of process used. Estimated costs for treatment of contaminated solids by solidification/stabilization using portland cement, pozzolans, and/or silicates are typically in the range of $50 to $75 per cubic yard.

- Summary. As a potentially effective (in reducing the mobility of contaminants), easily implemented, and typically low-cost technology, solidification/stabilization is retained for further evaluation. Treatability studies would be required to determine the effectiveness of solidification/stabilization with the contaminant/soil matrices at the ADA.

2.4.2.2.8 Ex Situ Treatment - Soil Washing. The physical separation of contaminated particles by washing with water, agitation, and particle classification is a potentially effective means to treat contaminated soil. When used on contaminated soil, this process makes use of the tendency of contaminants to concentrate in the finer particles (or fines) of soil leaving the larger particles relatively contaminant-free. Ideally, separation of the two ranges of particle sizes then allows for a significant reduction in soil volume to be treated.

- Effectiveness. The effectiveness of soil washing to physically concentrate contaminants by particle size classification is very dependent on specific soil and contaminant characteristics. Proof of its effectiveness for any given application would require feasibility/treatability testing. Soil washing using water to physically remove metals from soil has been demonstrated effective in specific applications [30,31]. Application of the technology has the potential to substantially reduce the volume of contaminated soil requiring further treatment or disposal. The soil washing technology is reportedly moderately to marginally effective for the removal of pesticides from soil. However, bench-scale studies conducted by USATHAMA indicate that removal efficiencies of explosive compounds are generally poor [32,34].

- Implementability. Equipment for on-site soil washing is readily available, mobile, and capable of processing contaminated soil at a wide range of throughputs [31]. The technology relies on the use of recycled water so there are no concerns regarding the storage and use of other extraction agents such as solvents or acids. Since the water is recycled, there are no concerns with the use of excessive amounts of water since it is a valuable resource at UMDA.

- Cost. The cost of soil washing to reduce the volume of contaminated soil is dependent on the total volume to be treated. A cost analysis performed for USATHAMA indicates that representative unit costs to treat soil at volumes required for remediation of ADA soils are roughly $60 per cubic yard of soil[31]. This analysis also included the comparison of costs associated with the solidification/stabilization and soil washing to identify the volume of soil at which soil washing as a pretreatment was economical. The results indicate that the cost effectiveness of soil washing is in doubt at volumes of approximately 5,000 cubic yards and less[30]. Since soil volumes at the ADA are greater than this, soil washing, if determined effective, may be attractive from a cost standpoint.

- Summary. Soil washing to reduce the volume of contaminated soil by concentrating the contaminants may be technically feasible and cost effective. Its effectiveness would require demonstration by feasibility/treatability testing. The process is relatively easily implemented. Because of the potential for effectiveness and cost reduction as well as implementability, soil washing as a pretreatment to reduce the contaminated volume is retained for detailed analysis.

2.4.2.2.9 Ex Situ Treatment - Incineration. A variety of thermal technologies exists for the treatment of solids containing organic contaminants. These techniques thermally oxidize or pyrolyze combustible pollutants at elevated temperatures, to produce the combustion products carbon dioxide and water. Other elemental constituents such as nitrogen, halogens, phosphorus, and sulfur are typically converted to acidic vapors. If the incinerated material contains metals, they may be retained in the ash, retained as particulates in the air pollution control system, or may be volatilized and released to the atmosphere.

Advantages of thermal treatment of wastes are:

- Toxic organic components are permanently converted to harmless or less harmful compounds.
- Thermal destruction of organic-contaminated material may be an ultimate treatment in itself, requiring no further treatment of residuals.

The most commonly used incineration process for the on-site treatment of contaminated soil is the rotary kiln incinerator. With this incinerator, waste is combusted in a refractory-lined kiln that is heated by burning fossil fuels. Exhaust gases pass through a secondary combustion chamber (afterburner) and air pollution control (APC) equipment. Minimal feed preparation is required. The primary residues generated are solid from the combustor (ash) and particulate from the APC. Scrubber water from the APC is generally recycled. Rotary kiln incinerators are the most versatile and the most proven of all devices for waste soil incineration.

On-site rotary kiln incinerators are available as either mobile or transportable units. Mobile units are small-capacity systems permanently installed on two or three trucks that are typically used at sites where the waste quantity ranges up to 20,000 tons. The incineration of larger volumes can be conducted more effectively using transportable system that occupy 5 to 30 trucks and that require on-site assembly.

- Effectiveness. Based on the general effectiveness of thermal destruction methods for organics, treatment by rotary kiln incineration has the potential to destroy organic contaminants to the maximum extent feasible. Full-scale field demonstrations of rotary kiln incineration have demonstrated a Destruction Removal Efficiency (DRE) of greater than 99.99 percent for soils containing explosive compounds[37]. Full-scale incineration of explosive-contaminated soils, using transportable rotary kiln incinerators, has been implemented at two Army installations[39,40]. Although potentially reducing the volume of contaminated soil, incineration does not result in the destruction of metals and is not an appropriate technology for the treatment of soil contaminated with only metals. It is, however, a feasible technology for the pretreatment of soil contaminated with both organics and metals for the removal of organics prior to subsequent treatment to remove or stabilize the metals.

- Implementability. The implementability of on-site rotary kiln incineration has been demonstrated on the full-scale to treat explosive-contaminated soil at two Army installations. Explosives concentrations in ADA soils do not appear to be a constraint. Studies conducted by USATHAMA indicate that sediments with explosive concentration levels higher than those in ADA soils can be fed directly to the primary combustion chamber of an incinerator without exceeding acceptable safety limitations[41].

- Cost. The unit cost of mobile and transportable rotary kiln incineration is highly dependent on the total mass of soil. Because of the fixed costs of site preparation, mobilization, and trial burns, the cost per ton increases as the total mass decreases. Unit operating costs have been estimated by two vendors of mobile rotary kiln incinerators and range from $250 to $750 per ton[42]. In the same survey, vendor

operating costs for transportable rotary kiln incinerators ranged from $200 to $450 per ton. These costs did not include excavation, site preparation, or solids handling. The results of another estimate indicated that total incineration costs for Superfund sites, including excavation, permitting, and ancillary equipment, were in the $200 to $650 per ton range. Total project costs for the incineration of explosives-contaminated soil at Cornhusker Army Ammunition Plant were $260 per ton (40,000 tons total)[39] and at Louisiana Army Ammunition Plant were $330 per ton (102,000 tons total)[40].

- Summary. On-site rotary kiln incineration is selected for further detailed evaluation because it is the single technology whose effectiveness and implementability have been demonstrated in similar applications involving organic (including explosives) contaminated soil.

2.4.2.2.10 Ex Situ Glassification. A variety of thermal technologies exists for the treatment of solids containing organic contaminants. These techniques thermally oxidize or pyrolyze combustible pollutants at elevated temperatures to produce the combustion products carbon dioxide and water. Other elemental constituents such as nitrogen, halogens, phosphorus, and sulfur are typically converted to acidic vapors. Thermal treatment for wastes containing significant concentrations of metals is a difficult process to operate and avoid volatilizing metals to the environment.

Advantages of thermal glassification of wastes include:

- Metals and inorganics will be fixed (and thus immobile).
- The technology is based on well-understood and developed technology.
- The glass product will be highly leach resistant.

Glass-making furnaces may be heated electrically (Joule heating) or by firing fossil fuels such as gas, oil, or coal. Preparation of the furnace feed, to minimize the amount of glass forming chemicals that would be required to produce a melt with the required viscosity at the operating temperature, would likely require judicious selection among the various clays, and sandy-soils. The glass forming chemicals to be added would probably be sodium alkalies, and we expect that perhaps as much as 25 weight percent of the furnace feed will be glass formers required to achieve satisfactory operation. For fossil fuel fired furnaces, sandy fine clays and sands may require agglomeration in order to reduce the entrainment of particulates into the offgas.

Because glassification must be carried out at high temperatures [typically 1200°C (2200°F)], the glass-making operation can generate fumes that are extremely difficult to remove from the offgases. For this reason, the air pollution control system may require

sophisticated equipment such as sonic scrubbers for removal of fumes and small size particulates. Depending upon the relative volatility of chemical species, it might be possible to return the scrubber liquid to the glassification furnace for incorporation of the captured particulates into the glass.

Chlorides and sulfates may create problems in glassification because these are not readily incorporated into the glass and are the source of fumes (e.g., sodium chloride will be a liquid with an appreciable vapor pressure at the operating temperature) which tend to exacerbate corrosion in the offgas handling equipment.

Because of the addition of glass formers and despite the density of the glass products, it is likely that the volume of the glassified product will be somewhat greater than the volume of materials processed.

- Effectiveness. The glassification technology has been shown to be effective with a variety of organic compounds and metals[36]. Glassification has not been demonstrated for use with explosives; however, extrapolation of results of incineration of explosive-contaminated soil at temperatures of 1500-1800°F [37] indicate that explosives would most likely be successfully oxidized at glassification temperatures.

- Implementability. Glassification makes use of well-established technology for the melting of glass. Glassification involves high temperature (typically 2200°F) treatment of contaminated solids for the purpose of destroying organic contaminants and immobilizing metals (and most other inorganics) contaminants in a glass residual product form. Organic components of wastes are thermally oxidized. Offgases are vented through a scrubber. Ash containing inorganic components is entrapped in the glass.

- Cost. The capital cost of a glass-making furnace is very high which makes it uneconomical for all but very large volumes of soil. Estimated capital costs of available glass-making furnaces are in the area of $38,000,000. Considering the volume of soils to be treated at the ADA, it is obvious that the per unit treatment cost is extremely high (nearly $1500 per cubic yard of soil treated for capital expenditure alone).

- Summary. Although glassification is a technically feasible option, due to the combination of relatively low volumes of soil to be treated and the high capital equipment cost, this alternative is eliminated from further consideration.

2.4.2.2.11 Off-Site Treatment and/or Disposal. Although the NCP specifies a preference for on-site remedies, there are certain circumstances in which off-site treatment and/or disposal may be preferable: particularly for smaller waste volumes. The potential for some of the ADA soils to exhibit the RCRA hazardous toxicity characteristic due to the presence of lead (and cadmium), would require that implementation of this option involve extensive analyses and segregation of soils according to their toxicity characteristic. Soil exhibiting the toxicity characteristic would require treatment prior to disposal. Other soils could be disposed of as nonhazardous wastes.

- Effectiveness. Removing the contaminated soil from the ADA would be effective in achieving the remedial action objectives.

- Implementability. The excavation of contaminated soil followed by transporting the soil to an off-site facility for treatment and/or disposal is one of the oldest and most established forms of soil remediation, particularly for small volumes of soil. It can be an expedient means of achieving the remedial action objectives. Implementability is negatively affected by requirements for manifesting and decontamination associated with transportation of the RCRA hazardous contaminated material. In addition, implementability may be affected by negative public opinion regarding movement of contaminated soil from the installation to a treatment/disposal facility.

- Cost. Costs for off-site treatment and/or disposal are dependent on the volume of soil involved, specific requirements for treatment, and availability and location of a suitable treatment/disposal facility. Estimated costs for excavation, transportation off-site, soil treatment, and residue disposal are $1,000 per cubic yard of RCRA hazardous soil requiring treatment prior to disposal. Costs for excavation, transportation off-site, and disposal of nonhazardous soil are estimated at $80 per cubic yard of soil.

- Summary. Off-site treatment and/or disposal would achieve the remedial action objectives and there is potential that it could be cost effective considering the relatively small volumes of soil involved. Implementation of the option may be negatively impacted by regulatory requirements and public opinion; however, off-site treatment and/or disposal has been a frequently used remedial alternative. Because of the potential for off-site treatment and/or disposal to be expediently implemented and cost effective, this alternative is retained for further consideration for the contaminated soils at the ADA.

3.0 Development of Alternatives

The two stages of screening potential technologies and process options for actions addressing soil contamination at the ADA, as described in Section 2.0, Identification and Screening of Technologies resulted in the selection of those technologies and process options that had potential applicability based on a determination of effectiveness, implementability, and cost. Those technologies and process options that survived the final screening were assembled and remedial alternatives were developed that consist of one or more of the options. These alternatives will be subjected to a detailed analysis that will be presented in Section 4.0, Detailed Analysis of Alternatives.

The developed alternatives with a summary of the primary actions involved in each of the alternatives are presented in Table 3-1 and are described in more detail below. Table 3-1 provides a reference to the identification of specific alternatives to be addressed in Section 4.0, Detailed Analysis of Alternatives.

3.1 Alternative 1: No Action

The No Action alternative serves as a common reference point for the analysis of alternatives that result in the remediation of the ADA. It provides a basis for comparison between the various alternatives. Implementation of the No Action alternative does not imply abandonment of the ADA. Existing security provisions to limit access to the ADA would be continued.

3.2 Alternative 2: Institutional Control and UXO Clearance

This alternative provides for the reduction of risks associated with future use of the ADA by conducting clearance of UXO to various levels. Institutional controls would be applied as appropriate to restrict access to and future use of the ADA consistent with the level of UXO clearance performed. No action would be taken to address chemical contamination of soil at the ADA.

This alternative consists of three options to address surface UXO clearance and subsurface clearance to depths of 1 and 5 feet. Because the locations and density of UXO at the ADA are unknown, it will be conservatively assumed, for the purposes of this evaluation, that clearance will be conducted across the entire ADA. Specific options are described below.

3.2.1 Alternative 2A

Specific actions required for the implementation of this alternative include:

- Clear UXO from the surface of the entire ADA.
- Limit future use to current restricted military use with vehicle access to roads only.

Table 3-1. Summary of Alternatives for the ADA

Alternative	General Alternative Description	Option	Option Description	Primary Option Actions
1	No Action	None		
2	Institutional Control, UXO Clearance	A	Restrict access, limit future use to military, clear surface of UXO	Clear UXO from surface of entire ADA
		B	Restrict access, limit future use to military, clear UXO to 1 foot	Clear UXO from the entire ADA to a depth of 1 foot
		C	Restrict access, limit future use to military, clear UXO to 5 feet	Clear UXO from the entire ADA to a depth of 5 feet
3	Institutional Control, UXO Clearance, Containment	A	Restrict access, limit future use to military, clear UXO, soil cover, vegetation	Clear UXO to 5 feet at chemically contaminated sites, place soil cover over chemically contaminated sites, plant vegetation over soil cover
		B	Restrict access, limit future use to military, clear UXO, engineered cap, vegetation	Clear UXO to 5 feet at chemically contaminated sites, place engineered cap/soil over chemically contaminated sites, plant vegetation over soil cover
4	Institutional Control, UXO Clearance, On-Site Treatment - Solidification/ Stabilization	A	Restrict access, clear UXO, pretreat by soil washing, S/S,off-site landfill of S/S residuals	Clear UXO from soils to be excavated, excavate chemically contaminated soil, soil wash to reduce volume, S/S of contaminated fraction, off-site landfill of treated materials
		B	Restrict access, clear UXO, pretreat by soil washing, S/S, on-site disposal of S/S residuals	Clear UXO from soils to be excavated, excavate chemically contaminated soil, soil wash to reduce volume, S/S contaminated fraction, on-site disposal of S/S residuals in active landfill (Option B[1]) or new landfill (Option B[2])
		C	Restrict access, clear UXO, S/S, off-site landfill of S/S residuals	Clear UXO from soils to be excavated, excavate chemically contaminated soil, S/S, off-site landfill of treated materials
		D	Restrict access, clear UXO, S/S/ on-site disposal of S/S residuals	Clear UXO from soils to be excavated, excavate chemically contaminated soil, S/S, on-site disposal of S/S residuals in active landfill (Option D[1]) or new landfill (Option D[2])

Table 3-1. Summary of Alternatives for the ADA (continued)

Alternative	General Alternative Description	Option	Option Description	Primary Option Actions
5	**Institutional Control, UXO Clearance, On-Site Treatment - Solidification/ Stabilization (S/S)**	A	Restrict access, clear UXO, pretreat by soil washing, incineration, S/S off-site landfill of S/S residuals	Clear UXO from soils to be excavated, excavate chemically contaminated soil, soil wash to reduce volume, incinerate organic fraction, S/S incinerator residuals and metal fraction, off-site landfill of S/S residuals
		B	Restrict access, clear UXO, pretreat by soil washing, incineration, S/S on-site landfill of S/S residuals	Clear UXO from soils to be excavated, excavate chemically contaminated soil, soil wash to reduce volume, incinerate organic fraction, S/S incinerator residuals and metal fraction, on-site disposal of S/S residuals in active landfill (Option B[1]) or new landfill (Option B[2])
		C	Restrict access, clear UXO, incineration, S/S, off-site landfill of S/S residuals	Clear UXO from soils to be excavated, excavate chemically contaminated soil, incinerate soil containing organics, S/S incinerator residuals and metal-contaminated soil, off-site disposal of S/S residuals in landfill
		D	Restrict access, clear UXO, incineration, S/S, on-site landfill of S/S residuals	Clear UXO from soils to be excavated, excavate chemically contaminated soil, incinerate soil containing organics, S/S incinerator residuals and metal-contaminated soil, on-site disposal of S/S residuals in active landfill (Option D[1]) or new landfill (Option D[2])
6	**Institutional Control, UXO Clearance, Off-Site Treatment and Disposal**	A	Restrict access, clear UXO, off-site treatment of hazardous soil, off-site disposal of non-hazardous soil	Clear UXO from soils to be excavated, excavate chemically contaminated soil, characterize soil, segregate hazardous and non-hazardous soils, transport soils off-site for treatment of hazardous soil and landfill disposal of non-hazardous soil
7	**Institutional Control, UXO Clearance On-Site Treatment and Disposal**	A	Restrict access, clear UXO, on-site treatment of hazardous soil, on-site disposal of treatment residuals and non-hazardous soil	Clear UXO from soils to be excavated, excavate chemically contaminated soil, characterize soil, segregate hazardous and non-hazardous soils, S/S hazardous soils, on-site disposal of non-hazardous soils and treatment residuals in active landfill (Option A[1]) or new landfill (Option A[2])

Source: Arthur D. Little, Inc.

3.2.2 Alternative 2B
Specific actions required for the implementation of this alternative include:

- Clear UXO to a depth of 1 foot from the entire ADA.
- Restrict future use of the ADA to military.

3.2.3 Alternative 2C - Specific actions required for the implementation of this alternative include:

- Clear UXO to a depth of 5 feet from the entire ADA.
- Restrict future use of the ADA to military, limited vehicle use, and/or foot traffic.

3.3 Alternative 3: Institutional Control, UXO Clearance, and Containment

This alternative is composed of two options that reflect the actions of placing institutional controls on future use of the ADA, clearing UXO from the contaminated areas, and on-site containment of the contaminated soil. Specific options are described below.

3.3.1 Alternative 3A
Specific actions required for the implementation of this alternative include:

- Clear UXO to the degree necessary to allow installation of the cap or cover (assumes clearance to 5 feet at the chemically contaminated areas).
- Place a layer of clean soil over the contaminated areas.
- Plant vegetation over the layer of clean soil.
- Employ institutional controls to limit future use of the ADA to the current restricted Army use with vehicle access on roads only.

3.3.2 Alternative 3B
Specific actions required for the implementation of this alternative include:

- Clear UXO to the degree necessary to allow installation of the cap or cover (assumes clearance to 5 feet at the chemically contaminated areas).
- Place an engineered cap covered by soil over the contaminated areas.
- Plant vegetation over the layer of clean soil.
- Employ institutional controls to limit future use of the ADA to the current restricted Army use with vehicle access on roads only.

3.4 Alternative 4: On-Site Soil Treatment - Solidification/Stabilization

Alternative 4 would provide for the remediation of the contaminated soil using the technology of solidification/stabilization. Institutional controls would be applied to restrict access to, and limit future use of, the ADA due to the presence of UXO. Four

options for this alternative are developed to address pretreatment of the soil to reduce its volume and the disposal of treatment residuals. These options are described below.

3.4.1 Alternative 4A

This alternative makes use of the soil washing technology to reduce the volume of contaminated soil to be treated by solidification/stabilization. Specific actions involved include:

- Clear UXO from contaminated soil to be excavated.
- Excavate contaminated soil.
- Conduct treatability studies of the use of soil washing and solidification/stabilization to determine effectiveness and process parameters.
- Pretreat excavated soil by soil washing to reduce the volume of contaminated material.
- Treat the contaminated fraction resulting from soil washing by solidification/stabilization.
- Confirm, by testing and analysis, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in an off-site landfill

3.4.2 Alternative 4B

This alternative differs from Alternative 4A in that on-site disposal of treatment residuals is considered instead of off-site disposal. Specific actions involved include:

- Clear UXO from contaminated soil to be excavated.
- Excavate contaminated soil.
- Conduct treatability studies of the use of soil washing and solidification/stabilization to determine effectiveness and process parameters.
- Pretreat excavated soil by soil washing to reduce the volume of contaminated material.
- Treat the contaminated fraction resulting from soil washing by solidification/stabilization.
- Confirm, by testing and analysis, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in the on-site active landfill (Option B[1]) or in a new, engineered, on-site landfill (Option B[2]).

3.4.3 Alternative 4C

In this alternative, the entire volume of contaminated soil is treated by solidification/stabilization, there is no pretreatment to reduce contaminated soil volume. Specific actions involved include:

- Clear UXO from contaminated soil to be excavated.
- Excavate contaminated soil.
- Conduct treatability studies of solidification/stabilization to determine effectiveness and process parameters.
- Treat contaminated soil by solidification/stabilization.
- Confirm, by testing and analysis, that treatment residuals are nonhazardous.

- Dispose of the treatment residuals in an off-site landfill.

3.4.4 Alternative 4D

This alternative differs from Alternative 4C in that on-site disposal of treatment residuals is considered instead of off-site disposal. Specific actions involved include:

- Clear UXO from contaminated soil to be excavated.
- Excavate contaminated soil.
- Conduct treatability studies of solidification/stabilization to determine effectiveness and process parameters.
- Treat contaminated soil by solidification/stabilization.
- Confirm, by testing and analysis, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in the on-site active landfill (Option D[1]) or in a new, engineered, on-site landfill (Option D[2]).

3.5 Alternative 5: On-Site Soil Treatment - Incineration and Solidification/Stabilization

Alternative 5 would provide for the remediation of the contaminated soil by incinerating the organic-contaminated soil and treating the incinerator residues and metal-contaminated soil by solidification/stabilization. Institutional controls would be applied to restrict access to, and limit future use of, the ADA due to the presence of UXO. Four options for this alternative are developed to address pretreatment of the soil to reduce its volume and the disposal of treatment residuals. These options are described below.

3.5.1 Alternative 5A

This alternative makes use of the soil washing technology to reduce the volume of contaminated soil to be treated by incineration and solidification/stabilization. Specific actions involved include:

- Clear UXO from contaminated soil to be excavated.
- Excavate contaminated soil.
- Conduct treatability studies of the use of soil washing and solidification/stabilization. to determine effectiveness and process parameters.
- Pretreat excavated soil by soil washing to reduce the volume of contaminated material.
- Mobilize mobile incinerator on site.
- Conduct trial burns.
- Incinerate concentrated organic-contaminated soil.
- Subject concentrated metal-contaminated soil and incinerator residues to solidification/stabilization.
- Confirm, by testing and analysis, that treatment residuals are nonhazardous
- Dispose of the treatment residuals in an off-site landfill.

3.5.2 Alternative 5B

This alternative differs from Alternative 5A in that on-site disposal of treatment residuals is considered in place of off-site disposal. Specific actions involved include:

- Clear UXO from contaminated soil to be excavated.
- Excavate contaminated soil.
- Conduct treatability studies of the use of soil washing and solidification/stabilization to determine effectiveness and process parameters.
- Pretreat excavated soil by soil washing to reduce the volume of contaminated material.
- Mobilize mobile incinerator on site.
- Conduct trial burns.
- Incinerate concentrated organic-contaminated soil.
- Subject concentrated metal-contaminated soil and incinerator residues to solidification/stabilization.
- Confirm, by testing and analysis, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in the on-site active landfill (Option B[1]) or in a new, engineered, on-site landfill (Option B[2]).

3.5.3 Alternative 5C

In this alternative, the entire volume of contaminated soil is treated by incineration and/or solidification/stabilization, there is no pretreatment to reduce contaminated soil volume. Specific actions involved include:

- Clear UXO from contaminated soil to be excavated.
- Excavate contaminated soil.
- Conduct treatability studies of solidification/stabilization to determine effectiveness and process parameters.
- Mobilize mobile incinerator on site.
- Conduct trial burns.
- Incinerate concentrated organic-contaminated soil.
- Subject concentrated metal-contaminated soil and incinerator residues to solidification/stabilization.
- Confirm, by testing and analysis, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in an off-site landfill.

3.5.4 Alternative 5D

This alternative differs from Alternative 5C in that on-site disposal of treatment residuals is considered in place of off-site disposal. Specific actions involved include:

- Clear UXO from contaminated soil to be excavated.
- Excavate contaminated soil.
- Conduct treatability studies of solidification/stabilization to determine effectiveness and process parameters.
- Mobilize mobile incinerator on site.
- Conduct trial burns.

- Incinerate concentrated organic-contaminated soil.
- Subject concentrated metal-contaminated soil and incinerator residues to solidification/stabilization.
- Confirm, by testing and analysis, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in the on-site active landfill (Option D[1]) or in a new, engineered, on-site landfill (Option D[2]).

3.6 Alternative 6: Off-Site Treatment and Disposal

Alternative 6 would provide for the removal of contaminated soil from UMDA for off-site treatment and disposal. Institutional controls would be applied to restrict access to, and limit future use of, the ADA due to the presence of UXO. The following actions would be involved in the implementation of this alternative:

- Clear UXO from contaminated soil to be excavated.
- Excavate contaminated soil.
- Determine hazardous characteristics of excavated contaminated soil.
- Segregate hazardous and nonhazardous contaminated soil.
- Prepare manifests for the transport of the hazardous contaminated soil.
- Transport hazardous and nonhazardous soil to a RCRA-permitted facility for the treatment of hazardous soil and the disposal of nonhazardous soil in a landfill.

3.7 Alternative 7: On-Site Treatment and Disposal

Alternative 7 would provide for the treatment and disposal of contaminated soil on-site. Institutional controls would be applied to restrict access to, and limit future use of, the ADA due to the presence of UXO. The following actions would be involved:

- Clear UXO from contaminated soil to be excavated.
- Excavate contaminated soil.
- Determine hazardous characteristics of excavated contaminated soil.
- Segregate hazardous and nonhazardous contaminated soil.
- Conduct treatability studies of solidification/stabilization to determine effectiveness and process parameters.
- Treat hazardous soil by solidification/stabilization.
- Confirm, by testing and analysis, that treatment residuals are nonhazardous.
- Dispose of the nonhazardous soil and treatment residuals in the on-site active landfill (Option A[1]) or in a new, engineered, on-site landfill (Option A[2]).

4.0 Detailed Analysis of Alternatives

The alternatives developed in Section 2.0, Identification and Screening of Technologies and Section 3.0, Development of Alternatives, are summarized in Table 3-1. For the ADA, seven basic alternatives are to be considered. Some of these alternatives include a number of options to provide adequate input to remedial alternative selection.

The purpose of this section of the FS is to present information relevant to selecting an appropriate remedy for the ADA. The analyses were performed in accordance with the requirements of the NCP, CERCLA, SARA, the Interim Guidance on Superfund Selection of Remedy, and the Oregon Hazardous Substance Remedial Action Rules. The analyses are also based on the institutional and technical criteria presented in Section 2.0, Identification and Screening of Technologies.

4.1 CERCLA Evaluation Criteria

The detailed analysis of alternatives consists of the evaluation and presentation of the relevant information needed to allow decision makers to select a site remedy. In developing this analysis there are five specific statutory requirements for remedial actions that must be addressed, including:

- Protection of human health and the environment
- Attainment of ARARs
- Cost-effectiveness
- Use of permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable
- Preference for treatment that reduces toxicity, mobility, and/or volume as the principal element

In addition, CERCLA places an emphasis on evaluating long-term effectiveness and related considerations for each of the alternatives, including:

- The long-term uncertainties associated with land disposal
- The goals, objectives, and requirements of the Solid Waste Disposal Act
- The persistence, toxicity, and mobility of hazardous substances and their constituents, and their propensity to bioaccumulate
- Short- and long-term potential for adverse health effects from human exposure
- Long-term maintenance costs
- The potential for future remedial action costs if the alternative remedial action in question were to fail
- The potential threat to human health and the environment associated with excavation, transportation, and redisposal, or containment

Each of these requirements and considerations were then combined in the NCP, and nine evaluation criteria were developed to address the intent of the requirements and

considerations and other technical and policy considerations that have proven to be important for selecting remedial alternatives. These nine evaluation criteria have served as the basis for conducting the detailed analysis of the nine remedial alternatives for the ADA. In order to ensure that the appropriate weight was applied to each of the criteria, the NCP divides the nine criteria into three groups (as shown in Figure 4-1): 1) Threshold Criteria; 2) Primary Balancing Criteria; and 3) Modifying Criteria.

4.1.1 Threshold Criteria

Two of the criteria relate directly to statutory requirements that must ultimately be satisfied in the ROD. They are categorized as threshold criteria because any alternative selected to remediate the ADA must meet them. They can be described as follows:

- Overall Protection of Human Health and the Environment - Describes how each alternative, as a whole, achieves and maintains protection of human health and the environment. This assessment draws on the assessments conducted under other evaluation criteria, especially long-term and short-term effectiveness and compliance with ARARs. It focuses on whether a specific alternative achieves adequate protection and describes how site risks are eliminated, reduced or controlled through treatment, engineering, or institutional controls.

- Compliance with ARARs - Describes how each alternative complies with ARARs, or if a waiver is required and how it is justified. The assessment also addresses other information from advisories, criteria, and guidance that the agencies agree is "to be considered." The detailed analysis summarizes which federal and State of Oregon requirements are applicable or relevant and appropriate for the specific alternative and how the alternative meets these requirements.

4.1.2 Primary Balancing Criteria

Five of the criteria are grouped together because they represent the primary factors upon which the analysis is based, taking into account technical, cost, institutional, and risk concerns.

- Long-Term Effectiveness and Permanence - Evaluates the effectiveness of each alternative in maintaining protection of human health and the environment after response objectives have been met. This assessment considers the magnitude of the residual risk (in this case, risk from contaminated soil that is not treated and risk from treatment residuals, if any), measured by numerical standards where possible. It also considers the adequacy and reliability of controls.

- Reduction of Toxicity, Mobility, and Volume through Treatment - Evaluates the anticipated performance of the specific treatment technologies each alternative might employ. Where possible, numerical comparisons before and after remediation are

Figure 4-1: Criteria for Detailed Analysis of Alternatives

Threshold Criteria

OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

- How Each Alternative Provides Human Health and Environmental Protection

COMPLIANCE WITH ARARs

- Compliance with Chemical-Specific ARARs
- Compliance with Action-Specific ARARs
- Compliance with Location-Specific ARARS
- Compliance with Other Criteria, Advisories, and Guidances

Primary Balancing Criteria

LONG-TERM EFFECTIVENESS AND PERMANENCE

- Magnitude of Residual Risk
- Adequacy and Reliability of Controls

REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

- Treatment Process Used and Materials Treated
- Amount of Hazardous Materials Destroyed or Treated
- Degree of Expected Reductions in Toxicity, Mobility, and Volume
- Degree to Which Treatment is Irreversible
- Type and Quantity of Residuals Remaining After Treatment

SHORT-TERM EFFECTIVENESS

- Protection of Community During Remedial Actions
- Protection of Workers During Remedial Actions
- Environmental Impacts
- Time Until Needed Remedial Action Objectives are Achieved

IMPLEMENTABILITY

- Ability to Construct and Operate the Technology
- Reliability of the Technology
- Ease of Undertaking Additional Remedial Actions, if Necessary
- Ability to Monitor Effectiveness of Remedy
- Ability to Obtain Approvals From Other Agencies
- Coordination With Other Agencies
- Availability of Necessary Equipment and Specialists
- Availability of Prospective Technologies

COST

- Capital Costs
- Operating and Maintenance Costs
- Present Worth Cost

Modifying Criteria

STATE ACCEPTANCE

COMMUNITY ACCEPTANCE

Source: EPA RI/FS Guidance Manual

presented. This assessment also considers the degree to which treatment is irreversible, the type and quantity of residuals that will remain following treatment, and the degree to which the treatment reduces the inherent hazards posed by the site.

- Short-Term Effectiveness - Examines the effectiveness of each alternative in protecting public health, worker health, and the environment during the construction and implementation of a remedy until response objectives have been met. The time until protection is achieved is also considered here.

- Implementability - Evaluates the technical and administrative feasibility of each alternative and the availability of required goods and services. Technical feasibility includes the ability to construct the system used, the ability to operate and maintain the equipment, and the ability to monitor and review the effectiveness of operations. Administrative feasibility refers to the ability to obtain normal legal approvals (e.g., site access), public relations and community response, and coordination with government regulatory agencies.

- Cost - Evaluates the capital and operation and maintenance (O&M) costs of each alternative. Capital cost refers to the expenditures required to develop and construct the facilities necessary to implement the alternative. O&M cost refers to the expenditures of time and materials throughout the course of the remediation, including costs to lease equipment. The costs presented in the detailed analysis are intended to provide an accuracy of +50 percent to -30 percent.

The level of detail required to analyze each alternative against these evaluation criteria depends on the type and complexity of the site, the type of technologies and alternatives being considered, and other project-specific considerations. This FS addresses soils at the ADA contaminated by metals, explosives, and/or pesticides. The detail presented in the following analysis has been focused accordingly.

4.1.3 Modifying Criteria

In accordance with RI/FS guidance, the final two criteria involving state and community acceptance will be evaluated following the receipt of state agency and public comments on the FS and the Proposed Plan. The criteria are as follows:

- State (Support Agency) Acceptance - Reflects the state of Oregon's apparent preferences among or concerns regarding the alternatives. State input and acceptance are obtained during preparation of the final FS and Proposed Plan through the state's role as an equal partner to the Army and EPA in the Federal Facility Agreement.

- Community Acceptance - Reflects the local communities' apparent preferences among or concerns about alternatives.

4.2 Analysis of Alternatives

4.2.1 Common Elements

The processes and procedures that are common to more than one of the remedial alternatives are presented here to minimize redundancy. Reference will be made to these common elements as appropriate in subsequent analyses of alternatives.

4.2.1.1 Institutional Controls. The implementation of institutional controls would involve taking legal and physical measures to restrict access and use of the ADA. Legal restrictions would have two purposes:

- Restricting access to the ADA to prevent direct human exposure to contaminants through legal limitations on who may conduct activities at the ADA (and where these activities may be conducted)

- Restricting future land use at the ADA to prevent, or limit, residential or light industrial development

If imposed, these legal restrictions would be retained permanently at the ADA.

One of the primary drivers for the need for institutional controls to be implemented at the ADA is the presence of UXO on the surface and in the subsurface. In consideration of the presence of UXO and the degree of UXO clearance to be performed, a likely option for institutional control at the ADA includes restricting future land use for limited and specific military training purposes only (implying that the ADA would remain fenced, in government control, and not released to the public). This assumes that surface clearance and, if required, shallow (1 to 5 feet) subsurface clearance of UXO would be performed.

Cost elements associated with the implementation of institutional controls include the costs of fencing (or maintenance of fencing), security, and monitoring. Since these costs will be incurred by the Army regardless of the remedial alternative selected, they are not provided in this FS.

4.2.1.2 Clearance of Unexploded Ordnance (UXO). Various scenarios that may be required to effect different degrees of UXO clearance are considered in this evaluation. These include:

- Total clearance of the entire 1,750-acre ADA (to include surface clearance and clearance to 1 and 5 feet
- Clearance of selected areas to allow for excavation of soil for remediation
- Total clearance (to 20 feet) of selected sites
- Subsurface clearance (to a maximum depth of 5 feet) of small areas (e.g., less than 20 acres) to allow for limited construction associated with site remediation

Cost estimates for each of these scenarios are presented below.

It should be noted that an analysis of UXO clearance in terms of time required and total cost is very site-specific. The time required to conduct a clearance is dependent on a number of factors. The most significant of these factors include: terrain, vegetation (particularly undergrowth), and density of metallic items (including ordnance items) on the surface and in the subsurface. As a first step in estimating the costs associated with UXO clearance, part of an economic model developed by the U.S. Navy was used to calculate the time required to clear UXO from the surface and subsurface[38]. This model provides for the calculation of time required as a function of terrain, vegetation, and item density. Clearance times were then combined with cost information provided by firms that specialize in UXO clearance to develop cost estimates for surface and subsurface clearance. Economy of scale is also a factor in the cost of clearance. The estimates provided immediately below for surface and subsurface clearance to 5 feet assume the clearance of 1,750 acres. An area of this magnitude may be considered to benefit from economy of scale.

At any level of UXO clearance operations, clearance of visible UXO from the ground surface is required. In typical surface clearance operations, a "sweep team" made up of several personnel walk abreast along established grids. The team members count and remove all metallic items. Explosive items encountered may be marked for later removal by explosive ordnance disposal-trained personnel[38]. Under optimum circumstances (i.e., flat terrain, little vegetation, and few metallic items), a typical sweep team composed of 10 personnel is capable of clearing a total of 40 acres/day[38]. A more conservative estimate of approximately 16 acres/day for a 10-member team was calculated based on the Navy model. At this rate, surface clearance of the entire ADA (assuming 1,750 acres) would require approximately 110 days. Corresponding clearance costs are estimated at approximately $500 per acre (including all reporting, emergency on-site personnel, and turnover of UXO). This estimate appears to be consistent with a recent estimate of $380 per acre provided to the Army for a recent surface clearance only (excludes emergency services, turnover and disposal of UXO, or any necessary site preparation) at an Army site[43]. To summarize:

Surface Clearance: Total time required (days): 110
Cost ($/acre): 500

As would be expected, the need for subsurface clearance has a significant impact on the time and cost of UXO clearance. According to vendors surveyed, the same basic effort is required whether detection and clearance is to 1 foot or to 5 feet [38,44]. The primary difference in time and cost is that the time to investigate, dig, and remove a deeper item is greater.

After a surface clearance has been completed, subsurface clearance is initiated by a subsurface survey usually conducted with hand-held magnetometers (metal detectors)

passed over the surface to detect subsurface items. There are a number of approaches to conducting the survey and clearance. An approach described by one experienced vendor includes the following steps:

- 1,000-foot long lanes are marked on the ground surface at 10-foot intervals.
- Each member of the team makes a pass with a magnetometer down each side of the lane providing an overlap of coverage of approximately percent.
- Metallic items identified to a depth of 12 inches are identified by probing and may be removed by hand during the survey.
- Metallic items identified at a depths of greater than 12 inches are flagged.
- After the survey, the flagged locations are revisited to remove the item by excavation with shovels or, if necessary, a backhoe.

Based on the sequence of events described above, assumptions were made to allow for the estimation of time required for subsurface clearance to a depth of 1 foot through the use of the Navy model. Specific assumptions include:

- A subsurface metallic density (to 1 foot) of 23 items per acre.
- Approximately 0.75 of an hour is required to investigate (and remove) each item.
- A 20-man team is used to conduct the clearance.
- An average of 6 hours per day for actual clearance.

Given these assumptions, the calculated rate of clearance is approximately 5 acres per day for a 20-member team. Clearance of the entire ADA to a depth of 1 foot would therefore require approximately 360 days. The cost of such a clearance is estimated at $3,000 per acre. In summary:

Subsurface Clearance (to 1 foot):	Total time required (days): 360 Cost ($/acre): 3,000

An estimation of time required for the conduct of a subsurface clearance to a depth of 5 feet is based on the same basic assumptions above with the exceptions that approximately 1.5 hours is required to investigate and remove each metallic item with an assumed density of 30 items per acre. The related calculated rate of clearance is approximately 2.3 acres per day for a 20-member team. Clearance of the entire ADA to a depth of 5 feet would therefore require approximately 760 days. The cost of such a clearance is estimated at $6,300 per acre. In summary:

Subsurface Clearance (to 5 feet) :	Total time required (days): 760 Cost ($/acre): 6,300

The second UXO clearance scenario considered is that which would permit the excavation of soil at the ADA. Soil excavation will be required for the remediation of chemically contaminated soil. Based on estimates provided by vendors, the cost of

conducting UXO clearance associated with soil excavation increases the cost of excavating contaminated soil ($8 per cubic yard) by a factor of 2.5 (or $12 per cubic yard additional cost for UXO clearance).

In addition to the estimates provided above, the cost of general UXO clearance to a depth of 20 feet has been estimated per acre cleared (for reference). It is assumed that removal to 20 feet would essentially result in a complete removal of UXO from that acre. The cost of clearance to a depth of 20 feet has been estimated at $516,000 per acre[38]. This is a rough estimate based on the cost to excavate to 20 feet under normal circumstances with a factor of four to account for the need to detect and clear UXO. Since such a clearance has not been conducted on a large scale, there are no real data to support this estimate. However, the estimate is consistent with an earlier reported estimate of about $12 per cubic yard to excavate soil to a depth of 10 feet, remove the ordnance and debris, and return the land to a near natural conditions [25].

Finally, the estimates for surface and subsurface (to 5 feet) clearance assume clearance of the entire 1,750 acres of the ADA. If clearance of small areas only (e.g., less than 20 acres) is required, there will be a minimum cost required to clear based on a minimum team of UXO personnel, and a minimum time on site. A minimum clearance cost has been estimated at $130,000. This cost represents a 5-member team on site for 20 days.

The costs presented above for subsurface clearance to depths of 1 and 5 feet are based on a manual survey with personnel carrying magnetometers over the site. There is the potential to reduce survey time and costs by employing a Surface Towed Ordnance Locator System (STOLS). The STOLS, developed under contract for the Navy, is an automated ordnance locator system using an all-terrain tow vehicle to pull a platform outfitted with an array of seven magnetometers. The tow vehicle is equipped with a computerized data acquisition system, a control panel, and a positioning system. Output from the magnetometers is input to the data acquisition system and locations of subsurface item detections are recorded by the positioning system. Once the survey is complete the data are analyzed by technicians to provide for the location of the subsurface item and an estimate of the size and depth of the item. The item can then be excavated, identified, and rendered safe or disposed.

One of the advantages of the STOLS is that it provides for a less personnel-intensive survey. It is estimated that in some cases, a survey using the STOLS can reduce costs associated with survey/subsurface clearance operations by as much as $300 per acre[24].

Efficient operation of the STOLS is dependent on site terrain and vegetation, the system cannot move efficiently through wooded areas or over rocky terrain. This limitation is not expected to be significant given the terrain and vegetation characteristics of the ADA.

Although the STOLS might possibly provide for less costly clearance operations, there is currently only a functional prototype available for testing and demonstration purposes.

Reliability and maintainability (RAM) testing has not been conducted on the system and repair parts and maintenance support systems have not been established [24]. Reportedly, the system is undergoing commercial development; however, the time frame for this development is unknown.

An additional consideration to the use of the STOLS is that the instrumented detection system is pulled behind a manned vehicle. Depending on specific site conditions, there may be a reluctance on the part of UXO clearance personnel to place a manned vehicle in advance of the UXO detection equipment.

Because of the current unavailability of the STOLS and the concerns imposed by the positioning of the manned tow vehicle before the detector array, consideration of the STOLS will not be included in the total analyses associated with UXO clearance.

4.2.1.3 Excavation of Soil. The implementation of Alternatives 4, 5, 6, and 7 involve the excavation of contaminated soils. At the ADA, excavation of soil will be complicated by requirements to identify and remove UXO. In addition to UXO clearance (described above), excavation of soil would be conducted as follows:

- Excavation and hauling would be done using conventional equipment and technology (e.g., backhoes, front-end loaders, dump trucks, scrapers).
- Excavation to a depth of 20 feet would require that sides of the excavation be sloped as appropriate for sideslope stability and shoring would not be required.
- The soil would be loaded on dump trucks and hauled to the treatment or disposal area.

Costs for excavation and loading associated with an unshored, uncontaminated excavation in similar circumstances have been estimated at approximately $4 per cubic yard of soil. Similar excavations involving contaminated soil are estimated at $8 per cubic yard.

Excavated sites will be restored by backfill with clean soil and revegetation with native plants.

4.2.1.4 Soil Washing to Reduce Contaminated Soil Volume. The physical separation of contaminated fine soil particles (e.g., silt and clay) from larger soil particles (e.g., sand) by washing with water, agitation and particle classification may be an effective method to reduce the volume of contaminated soil that requires subsequent treatment or disposal.

When used with contaminated soils, the soil washing process makes use of the fact that finer particles have a much larger surface area per unit volume than do larger soil particles. When the contaminants are uniformly distributed over the surface of the soil particles, a greater proportion of the contamination is concentrated on the fine soil

particles with their large surface area per unit volume, leaving the larger particles relatively free of contamination. Ideally, separation of the contaminated soil into fines that are highly contaminated and a relatively uncontaminated large particle fraction allows for a significant reduction in soil volume requiring further treatment or disposal. Soil (i.e., sand) that meets the cleanup levels can be returned to the site or otherwise disposed of as a nonhazardous solid waste.

Process Description. A representative soil washing process is presented in Figure 4-2. As shown, the excavated and stockpiled contaminated soil is screened to remove oversized (greater than 0.25 inch) particles and debris. The finer soil is conveyed to a spiral classifier where water is introduced and the separation of the fines from the sand occurs. The sand is dewatered and returned to the site or handled as a nonhazardous material. The resulting fines slurry is pumped to a settling tank where the fines settle as a sludge, leaving clear water to be recycled. A flocculating polymer may be added at this step to enhance settling, if necessary. After settling, the fines are pumped to a filter press for further dewatering. At this point, the concentrated and dewatered contaminated fines can be subjected to further treatment for toxicity reduction and/or solidification/stabilization.

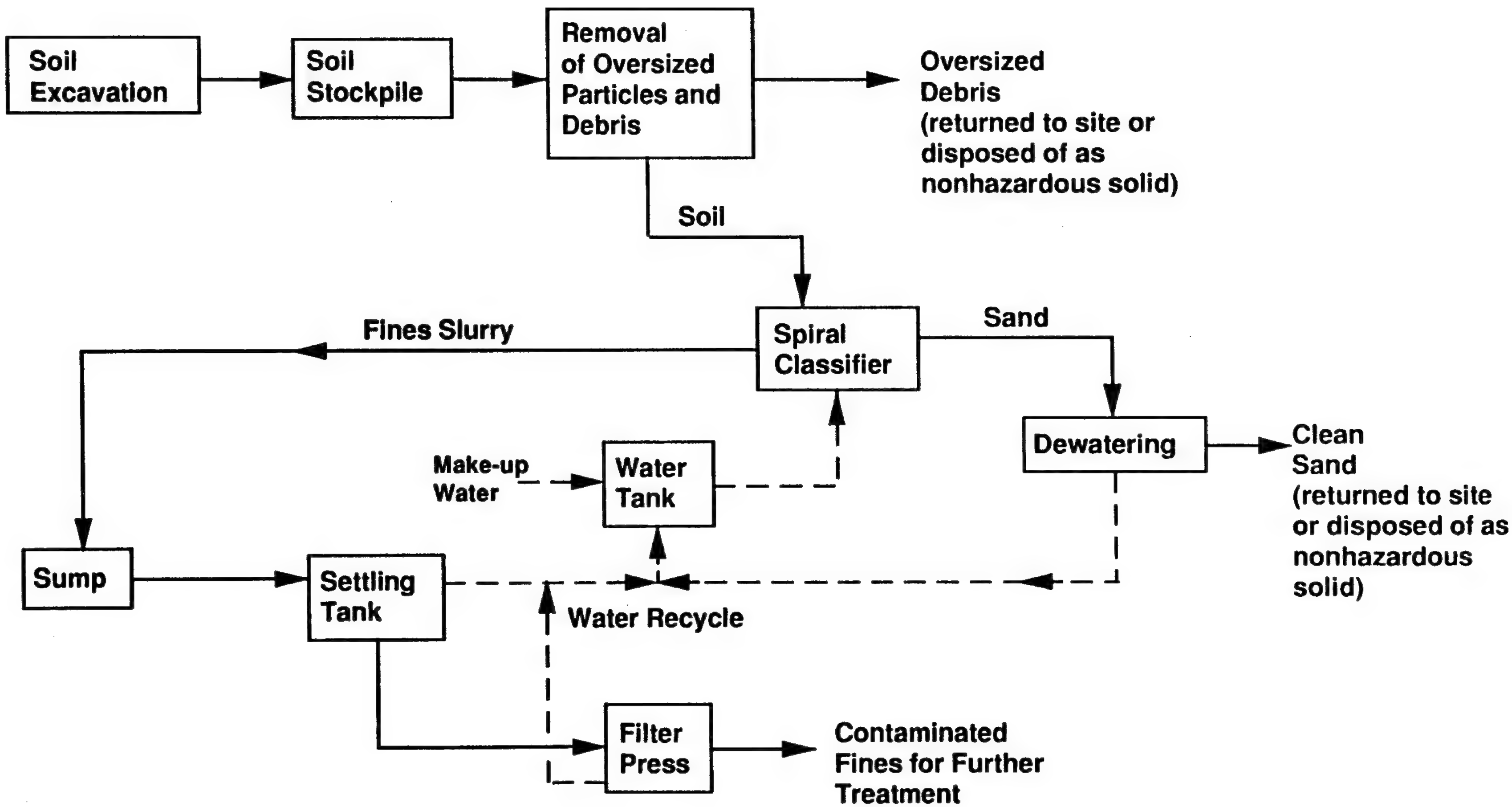
A review of the technology was performed for the EPA in support of a remedial alternative evaluation at the Deactivation Furnace site at UMDA. In this review, it was determined that, based on the particle size and contaminant distribution in these soils, the contaminated media could be concentrated to a volume that is 20 percent of the original soil volume [31]. Although similar particle size and contaminant distribution characterizations were not performed for ADA soils, it is assumed for the purpose of this evaluation that ADA soils are adequately similar to permit the same volume reduction assumption.

The low solubility of the contaminants of concern in water will most likely allow for the washwater to be recycled without treatment. It is assumed that once the soil washing process is complete, the water will be treated by lime precipitation in the existing settling tank to remove any soluble metals. If organic compounds are present in the water, further treatment by activated carbon adsorption may be necessary prior to discharge of the water. Based on the solubility of the contaminants in water, it may not be necessary to treat the water prior to discharge once the soil washing has been completed[31].

Soil washing is considered an innovative technology. As such, a treatability study would be required to confirm the effectiveness of the process; and identify operating parameters and develop cost estimates for full-scale implementation.

The primary cost elements of soil washing include capital costs associated with the purchase and installation of the various pieces of equipment used, and operating costs such as labor, maintenance, and utilities (electricity and water).

Figure 4-2: Schematic of Soil Washing Process



Source: Reference 31 and Arthur D. Little, Inc.

Assumptions regarding the implementation of soil washing include[31]:

- A nominal feed soil rate of approximately 9 tons per hour
- An operating schedule of 260 days per year, 8 hours per day, and 70 percent operational time on line.

4.2.1.5 Solidification/Stabilization. Solidification/stabilization has been proven most useful for the treatment of inorganic contaminants (including heavy metals). Its utility for the treatment of many organic-containing wastes may be limited due to the potential for detrimental chemical interactions, the volatility of the organic compounds, and limited success in reducing organic mobility. Because of the relatively low concentrations of nonvolatile organic contaminants in ADA soils, the likelihood for detrimental chemical interactions and volatility are lessened. However, the ability of the process to reduce the mobility of the organic contaminants is unknown and would require confirmation through treatability studies.

Process Description. Stabilization and solidification waste treatment processes involve the mixing of specialized additives or reagents with waste materials to reduce (physically or chemically) the solubility or mobility of contaminants in the matrix. The term "stabilization" is used to describe techniques that chemically modify the contaminant to form a less soluble, mobile, or toxic form without necessarily changing the physical characteristics of the waste. Solidification refers to a technique for changing the physical form of the waste to produce a solid structure in which the contaminant is mechanically trapped. Many stabilization and solidification processes overlap, and the common terminology to describe either or both processes is solidification/stabilization.

The types of processes and reagents used in solidification/stabilization processes will be selected based on the characteristics (chemical and physical) of the waste to be treated and on the desired characteristics (chemical and structural) of the treated product. Two common processes are:

- Lime/Fly Ash Pozzolan Reactions - involving a reaction between noncrystalline silica in fly ash and lime to produce a low-strength solid in which contaminants are physically trapped

- Pozzolan/Cement Reactions - which employ a pozzolan such as fly ash and cement to produce a relatively high-strength waste/concrete matrix in which contaminants are trapped

For the purposes of this FS, it will be assumed that the soil and ash to be treated will be subjected to a pozzolan/cement-based process to provide a treated product with maximum physical and chemical stability.

There are a number of configurations of the solidification/stabilization process including: in-drum mixing, in situ mixing, plant mixing, and area mixing[45]. Of these, plant mixing is the most practical for treating soils at the ADA because it provides for greater throughput, increased control of contaminated materials, increased assurance of treatment effectiveness, and can be performed with transportable equipment. A schematic of the plant mixing process is provided in Figure 4-3.

Transportable solidification/stabilization processes will typically come complete with chemical storage units, chemical feed equipment, mixing equipment, and waste and product handling equipment.

Primary concerns with the application of solidification/stabilization include:

- The potential chemical incompatibility between the material being treated and the solidification/stabilization reagents. For example, salts have been shown to cause swelling and cracking in solidified matrices[46].
- The long-term ability of the stabilized/solidified matrix to retain the contaminants. Since solidification/stabilization processes normally do not destroy the contaminant but, rather, place it in a nonleachable form, the long-term integrity of the product must be assured.

These concerns can best be addressed through the conduct of treatability testing. The treatability test will also allow for the development of proper design and operation criteria.

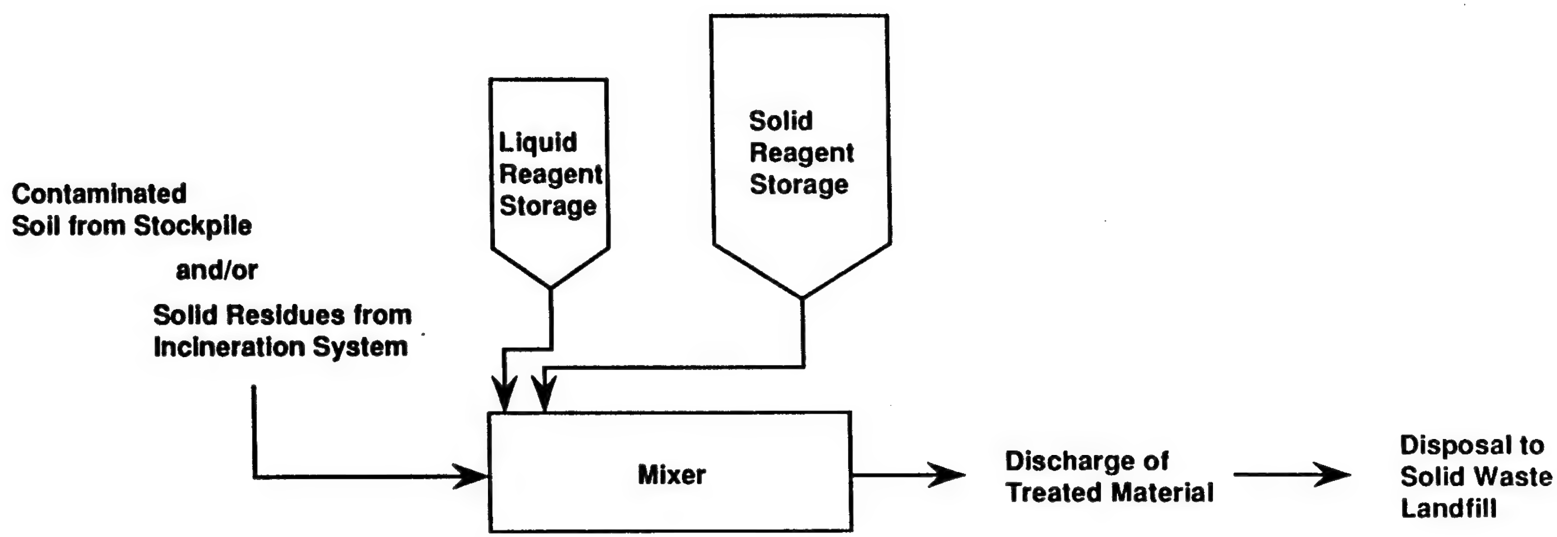
Implementation of solidification/stabilization would require sufficient land area around the operation to maintain a buffer zone, access roads capable of supporting heavy equipment (in this case, 80,000 lb trailers), and direct and unencumbered accessibility to the waste feed material.

The actual equipment set-up for solidification/stabilization requires area for reagent storage tanks, mixer (or pugmill), and loading equipment. Approximately 0.25 acres will be required for the equipment alone. Additional area is required for loading and unloading soil and treated material, untreated and treated material stockpiles, and truck access.

As stated above, there are a number of options available for management of the treated product. For the purposes of this analysis, it is assumed that the treated product will be discharged to a dump truck, roll-off boxes, or other transportable containers for transport to the final disposal area.

Utility requirements for solidification/stabilization will include:

Figure 4-3: Schematic of Stabilization/Solidification Process



Source: Arthur D. Little, Inc.

- A continuous water supply at 60 psi to be used in the treatment reaction. For the purposes of analysis, it is assumed that this water will be available from installation sources. However, if supplies at the treatment site are insufficient, an alternate supply (from on or off the installation) will be required.

- Electrical service of 480V, 3-phase for major equipment operation. In addition, the operation of ancillary operation and support systems will require 15 amp, 120-V, 1-phase service. For the purposes of this analysis, it is assumed that these electrical requirements can be met on the installation.

Approximately 12 to 15 personnel are required to operate the system in a single 10 to 12 hour shift, 6 days per week[47]. These personnel include operators, supervisor, shift foreman, and maintenance personnel. Individual shifts are long to ensure that once the chemical reagents are mixed, they continue to flow without hardening. Typically, maintenance is performed on the seventh day when the system is shut down.

The following testing phases are performed to develop operational parameters and assure quality control of the treated product:

- Waste characterization includes a determination of physical properties of the contaminated soil to include: bulk density, grain size distribution, atterberg limits (liquid and plastic), cone index, unconfined compressive strength, and percent moisture. In addition, analyses are performed to identify chemical characteristics that may affect the solidification/stabilization process including acids, solvents, halides, sulfates, pH, metals, solid organic contaminants, oil, and grease.

- Treatability tests will be required to select the appropriate reagent systems and optimize process parameters.

- To assess the quality of the final product, a series of tests are typically performed to determine product characteristics such as leachability, free liquid content, strength, permeability, and durability.

Complete mobilization of the solidification/stabilization system will typically require approximately six weeks from the completion of treatability testing. Once operational, the time required to complete the solidification/stabilization of the contaminated media will depend on the total mass to be treated, the throughput, and the operating efficiency. The former factor is alternative-dependent and will be addressed in the discussion of the specific remedial alternatives below. The latter two factors are alternative-independent and assumptions specific to these factors are:

- Operating schedule of 12 hours, 6 days per week with an operating on line time of 70 percent

- Throughput of process is nominally 350 tons/day (including material to be treated and reagents)[47]

4.2.1.6 On-Site Landfill Disposal of Nonhazardous Soil and/or Treatment Residues. As part of the remediation of soil at the ADA, soil may be excavated that, although contaminated to the degree that it does not meet remedial action goals, is not a RCRA hazardous waste. In addition, residuals resulting from the excavation and treatment of contaminated soil (including rocks and debris separated from the soil prior to treatment, solid treatment byproducts, and the final solid treatment product) may be nonhazardous. A potential disposal option considered for these nonhazardous solids is disposition in the active on-site landfill or in a new, engineered landfill that would be constructed on site.

The existing active landfill, shown in Figure 4-4, is located in the eastern portion of UMDA between munitions storage blocks D and E. Under an agreement entered into by the Army, this landfill ceases receipt of municipal waste on October 9, 1993, but may receive treated soil from the Deactivation Furnace Area (or other nonhazardous clean-up wastes or soils meeting similar standards) until late March 1998.[48] The Army is currently in the process of preparing a closure plan for the landfill in accordance with its permit and ODEQ solid waste regulations and guidance. As part of landfill closure requirements, the following actions will be performed:

- The landfill will be capped with a low permeability cap consisting of 18 inches of compacted soil with a permeability no greater than $1x10^{-5}$ cm/second.
- Ground water monitoring will be performed for a period of five years after closure to ensure that the landfill does not constitute a source of contamination.

If it is determined that disposal of these nonhazardous solids in the active landfill is not desired, a new engineered landfill might be designed and constructed on site to receive them. This landfill would be designed and constructed to meet ODEQ solid waste regulations and be located at an appropriate (currently undetermined) location within UMDA. After all nonhazardous solids resulting from the remedial actions at UMDA are deposited in the landfill, it would be closed in accordance with requirements of its permit and ODEQ solid waste regulations and guidance. It is assumed that closure of this landfill will include a cap of compacted soil similar to that proposed for the active landfill as well as ground water monitoring for a period of five years after closure. Regardless of the option pursued (existing landfill or new landfill), all solid material considered for disposal would require sampling and analysis to confirm that it is nonhazardous.

Costs for transporting the nonhazardous solids from the ADA to either the active landfill or a new landfill are estimated at approximately $4 per cubic yard of nonhazardous solids to be disposed of. Costs associated with the design and construction of a new landfill will total approximately $1.3 million.

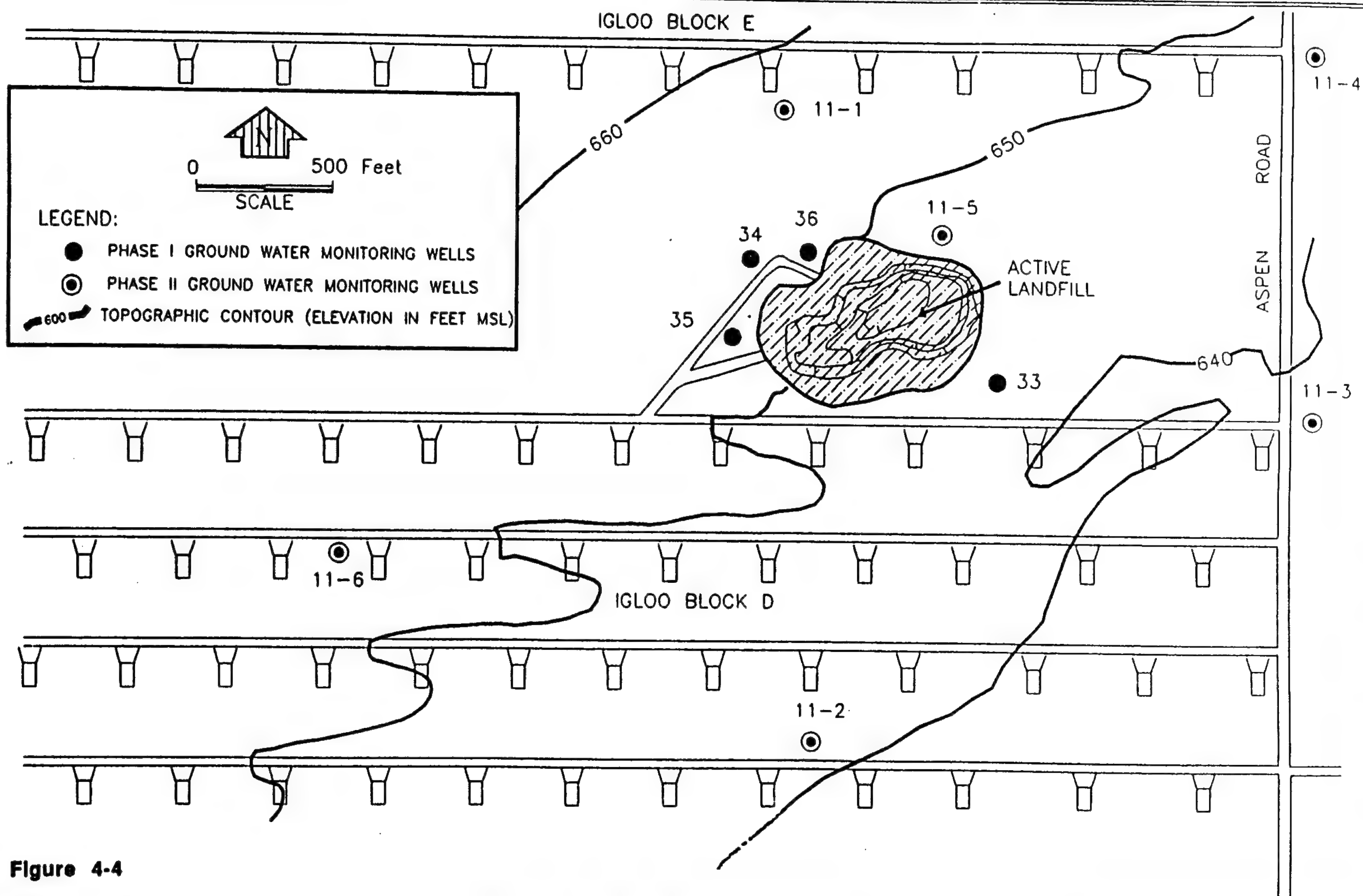


Figure 4-4

PREPARED FOR: UMATILLA			Modified From: Final Remedial Investigation Report for the Umatilla Depot Activity, Hermiston, OR, August, 1992	TITLE: ACTIVE LANDFILL
DATE: SEPT.1992	SCALE: AS SHOWN	DWG. NO. 67062-003		

The cost of closure of the existing active landfill (a separate OU) is included in the overall closure plan for that landfill and is not included here. The cost of closure of a new on-site landfill is estimated at approximately $24 per cubic yard of material disposed.

4.2.1.7 Preparation of Remedial Design and Planning Documentation. A number of Remedial Design/Remedial Action planning documents may be required for implementation of a given alternative. These plans may include: Work Plan; Materials Handling Plan; Chemical Data Acquisition Plan; Trial Burn Plan; Erosion and Sedimentation Control Plan; Security Plan; Safety Plan; Traffic Control Plan; and Environmental Protection Plan. The extent and detail to which planning documentation will be required will depend on the specific processes to be employed in the remedial action and the complexity of the on-site remedial action activities. Based on previous remedial activities conducted by the Army, these costs are estimated at 10 percent of the total capital and O&M costs.

4.2.1.8 Additional Costs for Sampling and Analysis. Additional sampling and analysis may be required for site characterization or confirmation during and/or after remediation. Some of these costs will be incurred by the Army regardless of the alternative selected (with the exception of No Action). These costs are included in the contingency costs allowances as part of the indirect capital cost.

4.2.2 Alternative 1: No Action

4.2.2.1 Description of Alternative. According to the NCP, remedy selection must include an analysis of the level of treatment with respect to the expenditures of time and materials required to achieve that level. The No Action alternative serves as a common reference point for this analysis and allows for comparisons between the various alternatives.

No Action does not imply immediate abandonment of the ADA. Existing security provisions to limit access to the ADA would be continued.

Natural recovery of the contaminated soil is unlikely at the ADA due to the characteristics of the dominant contaminants. The contaminants are nonvolatile and therefore their volatilization from soil at ambient temperatures is unlikely. In addition, due to the low organic content of the ADA soils as well as the relative resistance of the contaminants to biodegradation, degradation of the contaminants is unlikely. The primary mechanism that may serve to reduce contaminant concentrations is their dispersion (and resulting dilution) by wind. This mechanism is applicable to surface soils only.

The primary route of migration of contaminants in soil at the ADA is through windblown dust. A course of No Action would do nothing to limit the potential for contaminant migration.

4.2.2.2 ***NCP Criteria Analysis.*** The degree to which the No Action alternative satisfies the seven threshold and primary balancing criteria of the NCP is discussed below.

Overall Protection of Human Health and the Environment. This alternative does nothing to enhance protection of adjacent communities, the environment, or future land users. The risks posed by the soil would remain at the current level.

The No Action alternative would present only a minimal risk of exposure to UMDA personnel during routine site activities. The site is removed from areas of active use, so direct contact with soils would not be expected. However, exposure via the air pathway would be of concern due to the potential for windblown dust at the ADA. This alternative would not require any further construction or operation activities.

UXO would remain on the surface and in the subsurface and would continue to present safety hazards to anyone using the ADA other than on the established, cleared roads.

Compliance with ARARs. This alternative would not comply with either state or federal ARARs regarding soil remediation. The excess cancer risk values for potential future exposure at some sites would exceed the acceptable range of 1×10^{-4} to 1×10^{-6} as stated in the NCP (40 CFR 300.430[e][2}[i][A][2]). Likewise, the state of Oregon requires a cleanup to background or, when background is not feasible, to that lowest level that is protective of human health and the environment while cost effective. The No Action alternative does not demonstrate a remedial effort that results in protection of human health or the environment.

Long-Term Effectiveness. This alternative provides no long-term protection of human health and the environment, and the potential for direct exposure to future site users remains.

Reduction in Toxicity, Mobility, and Volume. The No Action alternative achieves little, if any, reduction in the toxicity, mobility, or volume of the contaminants present.

The primary route of migration of contaminants in soil at the ADA is through windblown dust. A course of No Action would do nothing to limit the potential for contaminant mobility or migration.

Short-Term Effectiveness. Since no remedial activities are conducted, there would be no short-term impacts to workers, the public, or the environment.

Implementability. There are no practical impediments to implementation of this alternative. However, there are administrative considerations that may impact its overall implementability. Among these considerations are: regulatory preference for cleanup; the

potential for future use restrictions to be imposed as a result of the continued existence of contamination at the ADA; and potential liabilities associated with the continued presence of UXO on the surface or in the subsurface.

Cost. The immediate costs for implementing the No Action alternative would be minimal. However, because the site could pose unacceptable risks to future industrial or residential users, the Army might be required to retain ownership of the ADA and provide long-term monitoring and management. These costs, while potentially substantial, have not been estimated in this FS because of their indefinite nature.

4.2.3 Alternative 2: Institutional Control and UXO Clearance

4.2.3.1 Description of Alternative. This alternative provides for various degrees of clearance of UXO from the ADA. Three options are evaluated:

- Option A–Surface clearance
- Option B–Clearance to a depth of 1 foot
- Option C–Clearance to a depth of 5 feet

Each of these options is described in Section 4.2.1.2, Clearance of Unexploded Ordnance (UXO).

It is assumed for this analysis that each of these options would be applied across the entire 1,750-acre ADA site. It is unlikely that UXO are present either on the surface or in the subsurface across this entire area. However, since the locations and frequency of occurrence of UXO at the ADA are unknown, requirements for clearance are conservatively assumed to encompass the entire 1,750 acres.

This alternative provides for reductions in the safety risks associated with potential exposure to UXO – it does not provide for any action to be taken with respect to chemical contamination of the ADA soils. Natural recovery of the contaminated soil is unlikely at the ADA due to the characteristics of the dominant contaminants. The contaminants are nonvolatile and therefore their volatilization from soil at ambient temperatures is unlikely. In addition, due to the low organic content of the ADA soils as well as the relative resistance of the contaminants to biodegradation, degradation of the contaminants is unlikely. The primary mechanism that may serve to reduce contaminant concentrations is their dispersion (and resulting dilution) by wind. This mechanism is applicable to surface soils only.

The primary route of migration of contaminants in soil at the ADA is through windblown dust. This alternative would do nothing to limit the potential for contaminant migration.

4.2.3.2 NCP Criteria Analysis. The degree to which this alternative satisfies the seven threshold and primary balancing criteria of the NCP is discussed below.

Overall Protection of Human Health and the Environment. This alternative provides for a degree of reduction of safety risks associated with potential exposure to UXO. However, implementation of the alternative does nothing to enhance protection of adjacent communities, the environment, or future land users with respect to the risks and hazards associated with chemically contaminated soil.

This alternative would present only a minimal risk of exposure to chemically contaminated soils by UMDA personnel during routine site activities. The site is removed from areas of active use, so direct contact with soils would not be expected. However, exposure via the air pathway would be of concern due to the potential for windblown dust at the ADA.

Compliance with ARARs. This alternative would not comply with either state or federal ARARs regarding soil remediation. The excess cancer risk values at some sites would exceed the acceptable range of 1×10^{-4} to 1×10^{-6} as stated in the NCP (40 CFR 300.430[e][2}[i][A][2]). Likewise, the state of Oregon requires a cleanup to background or, when background is not feasible, to that lowest level that is protective of human health and the environment while cost effective. This alternative does not demonstrate a remedial effort that results in protection of human health or the environment beyond that achieved by reducing the levels of surface and subsurface UXO.

The clearance of UXO to the degrees specified in this alternative would comply with the proposed standards presented in Figure 2-4.

Long-Term Effectiveness. This alternative provides no long-term protection of human health and the environment from the risks and hazards associated with chemically contaminated soil, and the potential for direct exposure to future site users remains. The clearance of UXO will permanently reduce the risks associated with their presence at the ADA.

Reduction in Toxicity, Mobility, and Volume. This alternative achieves little, if any, reduction in the toxicity, mobility, or volume of the chemical contaminants present in ADA soils. The volume of contaminants as represented by UXO would be reduced.

The primary route of migration of contaminants in soil at the ADA is through windblown dust. This alternative would do nothing to limit the potential for chemical contaminant mobility or migration.

Short-Term Effectiveness. Risks associated with the clearance of UXO will be minimized by control of the area and the use of experienced personnel thoroughly trained in explosive safety.

The objectives of each of the options could be reached in a relatively short time period ranging from 4 to 20 months.

Implementability. There are no practical impediments to implementation of this alternative. However, there are administrative considerations that may impact its overall implementability. Among these considerations are: regulatory preference for cleanup; the potential for future use restrictions to be imposed as a result of the continued existence of contamination at the ADA; and potential liabilities associated with the continued presence of UXO in the subsurface.

Surface and subsurface clearance of UXO has been demonstrated. There is a competitive field of firms that specialize in UXO clearance.

Cost. Cost estimates developed for this alternative were made based on engineering calculations, vendor estimates, and other documented sources. A summary of capital and O&M costs for the implementation of the options of Alternative 2 is presented in Table 4-1.

4.2.4 Alternative 3: Institutional Control, UXO Clearance, and Containment

4.2.4.1 Description of Alternative. This alternative involves the imposition of institutional controls on the ADA to limit access to (and future use of) the area. The issues and implications of institutional controls are described in Section 4.2.1.1, Institutional Controls. In addition to the imposition of institutional controls, this alternative involves the clearance of UXO to the degree necessary to allow installation of the cap or cover (assumes clearance to 5 feet at chemically contaminated areas). The final part of this alternative involves the containment of contaminated soil at the ADA by the use of a soil cover with vegetation or a clay/soil cap with vegetation.

The primary purposes of containment of contaminated soil at the ADA by the use of a soil cover or an engineered (i.e., clay/soil) cap are to minimize direct contact with contaminated soil and reduce the mobility of the contaminants by preventing their dispersion as windborne dust. A secondary benefit to a soil cover or cap would be the limitation of infiltration from precipitation.

The soil cover under consideration consists of an 18-inch layer of clean soil obtained from uncontaminated areas at UMDA. The clay/soil cap consists of a 24-inch layer of clay covered by 18 inches of soil and gravel.

Activities involved in placing either the soil cover or clay/soil cap include clearing, grubbing, and grading. Once the soil or clay has been placed, it is compacted to the maximum extent possible and vegetation is placed over the cover or cap.

Table 4-1: Alternative 2
Institutional Control and UXO Clearance

Element	Alternative Option (1993 dollars)		
	2A	2B	2C
Capital Cost			
UXO Clearance	875,000	5,250,000	11,025,000
Contingency	219,000	1,310,000	2,756,000
Total Capital	$1,094,000	$6,560,000	$13,781,000
O&M Cost			
5 Year Review	6,400	6,400	6,400
Contingency	1,600	1,600	1,600
Total O&M	$8,000	$8,000	$8,000
Remedial Design/Planning	$110,000	$657,000	$1,379,000
Total Cost	**$1,212,000**	**$7,225,000**	**$15,168,000**

Source: Arthur D. Little, Inc.

4.2.4.2 NCP Criteria Analysis.

Overall Protection of Human Health and the Environment. The potential for presence of the UXO in the subsurface of the ADA will require that institutional controls be applied to prevent any subsurface disturbance that could uncover buried UXO. This essentially eliminates the potential for any future use of the area other than limited use for military purposes (e.g., as a firing range). The containment of contaminated soils by the placement of a soil cover or clay cap would minimize the exposure of military personnel to the contaminants as well as prevent the spread of contaminants as windborne dust. Because of the limited activity imposed by the institutional controls, it would be expected that the lifetime of a soil cover or clay cap would be increased with minimal long-term maintenance or monitoring required.

It is expected that containment by a soil cover or clay cap would allow for protection of human health and the environment by reducing the potential for direct contact as well as dispersion of the contaminants as windborne dust.

Compliance with ARARs. The use of containment techniques comply with chemical-specific ARARs with respect to prevention of exposure to unacceptable levels of contamination. However, the techniques do not satisfy the statutory preference for treatment. Since little or no natural attenuation is expected to occur with time, the levels of contamination would essentially remain unchanged.

The activities involved in the implementation of Alternative 3 would not be expected to affect protected species present at the UMDA facility, nor affect any off-site designated wetlands.

All actions associated with this alternative can be adequately controlled so that action-specific ARARs can be met. Dust emission sources will be monitored during the handling of the soils and clays to be used for covers or caps. Since the contaminated soil is not excavated and removed, RCRA LDR requirements do not apply.

The continued presence of UXO at the surface and in the subsurface would require that institutional controls to restrict access and limit use be maintained.

Long-term Effectiveness and Permanence. Under normal circumstances, soil covers or caps are not considered to be either long-term or permanent solutions to the spread of contamination. However, through the imposition of institutional controls (i.e., fencing and future use restrictions) to limit future activities at the ADA, it is expected that the long-term effectiveness and permanence of these methods of containment will be significantly increased.

Since only a limited level of UXO clearance would be performed to allow installation of the cap or cover, clearance would not provide along-term, permanent solution to the

presence of UXO. The long-term and permanent application of institutional controls, however, would provide for protection of human health and safety.

Reduction of Toxicity, Mobility, and Volume. The use of soil covers or caps does not affect the toxicity or volume of contaminants. Containment by covers or caps does decrease the mobility of the contaminants by providing barriers to their dissemination as windborne dust as well as providing a barrier to water infiltration.

There is no aspect of this alternative that provides for treatment of the contaminated soil; therefore, this alternative does not satisfy statutory preference for treatment as a principal element of a remedial activity.

Short-term Effectiveness. The protection of the environment, the surrounding community, and workers during implementation of this alternative can be maintained by applying adequate controls during the handling of soil and clay materials. Additional protection of the environment from adverse impact will be ensured by the restoration of the contained areas to near-natural conditions by planting vegetation over the covers or caps.

Risks associated with the clearance of UXO will be minimized by control of the area and the use of experienced personnel thoroughly trained in explosive safety.

The time required to implement this alternative is estimated at eight months.

Implementability. The technical feasibility of the actions involved in the implementation of this alternative has been demonstrated.

Materials and services for the installation of soil covers and engineered caps are readily available. Their installation is performed with conventional earth moving, loading and compaction equipment and little or no specialized expertise is required.

There is a competitive field of firms that specialize in the clearance of UXO.

Cost. Cost estimates developed for this alternative were made based on engineering calculations, vendor estimates, other documented sources, and experience. A summary of capital and O&M costs for the implementation of the various options of Alternative 3 is presented in Table 4-2. A detailed breakdown of these costs is provided in Appendix C.

4.2.5 Alternative 4: On-Site Treatment by Solidification/Stabilization

4.2.5.1 Description of Alternative. The core of this alternative involves the on-site treatment of all excavated contaminated soils by solidification/stabilization. In addition, options are presented that make use of soil washing to reduce the volume of soil

Table 4-2: Alternative 3
Institutional Control, UXO Clearance, and Containment

Element	Alternative Option (1993 Dollars) 3A	3B
Capital Cost		
UXO Clearance	130,000	130,000
Soil Cover	186,000	
Engineered Cap		341,000
Contingency	79,000	118,000
Total Capital	$395,000	$589,000
O&M Cost		
5 Year Review	6,400	6,400
Contingency	1,600	1,600
Total O&M	8,000	8,000
Remedial Design/Planning	40,000	60,000
Total Cost	**$443,000**	**$657,000**

Source: Arthur D. Little, Inc.

to be subjected to solidification/stabilization. Other options reflect the ultimate disposal of the treated solids including: (1) on-site disposal in the existing active landfill; (2) on-site disposal in a new landfill; and (3) off-site disposal in a solid waste landfill.

A discussion of the soil washing process is provided in Section 4.2.1.4, Soil Washing to Reduce Contaminated Soil Volume. The solidification/stabilization process is described in Section 4.2.1.5, Solidification/Stabilization. A description of on-site disposal of treatment residues is provided in Section 4.2.1.6, On-Site Landfill Disposal of Nonhazardous Soil and/or Treatment Residues. Aspects of the implementation of those processes that are specific to this alternative are discussed below.

Clearance of UXO will be performed as necessary to permit excavation of contaminated soil.

Integration of Processes. Schematics of the integration of the various processes and options involved in this alternative are presented in Figures 4-5 and 4-6. For the purposes of this analysis, it is assumed that pretreatment by soil washing (for those options involving pretreatment) will be completed prior to the startup of the solidification/stabilization process. By staging the operations in this manner, operation of the solidification/stabilization process can be conducted independently of soil washing allowing for a continuity of feed to the process.

Procurement, site preparation, and treatability testing required for the solidification/stabilization process can occur during the time of pretreatment by soil washing.

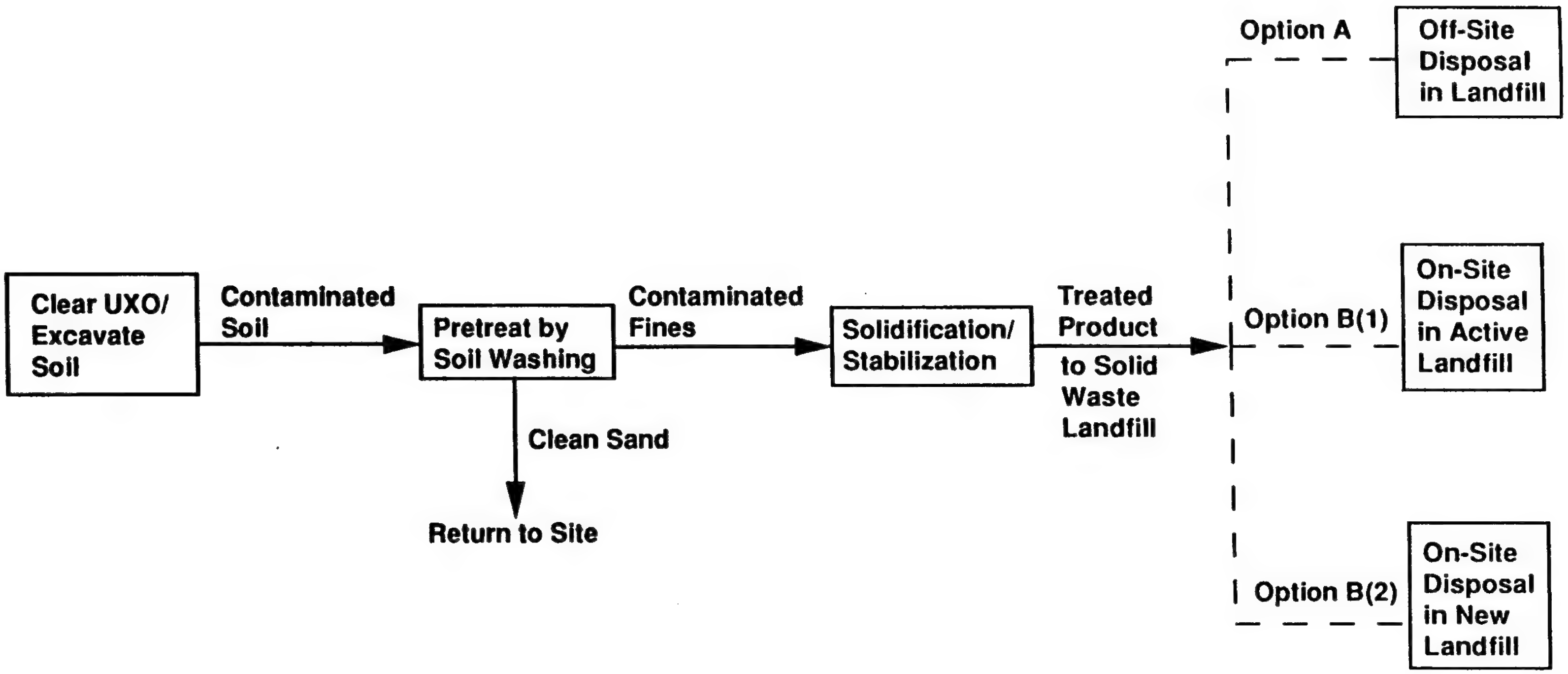
4.2.5.2 NCP Criteria Analysis. The results of an evaluation of Alternative 4 with respect to the screening criteria described in Section 4.1, CERCLA Evaluation Criteria are provided below.

Overall Protection of Human Health and Environment. This alternative would provide for overall protection of human health and the environment and meet the Remedial Action Objectives by immobilizing the contaminants of concern. Solidification/stabilization of contaminated soil would result in immobilization of metals. The degree to which organic contaminants would be immobilized would require determination in treatability testing. The treated product will be removed to a solid waste landfill which will provide for continued protection of human health and environment.

Protection of human health and the environment during remediation would be achieved by:

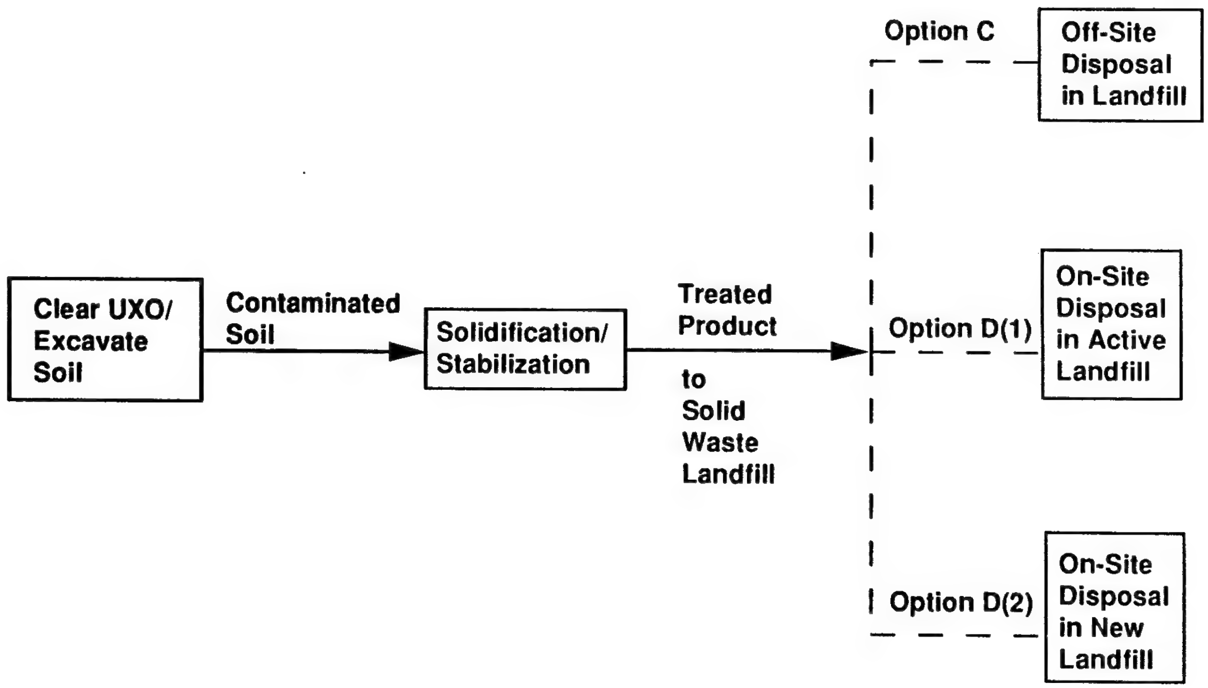
- Adherence to design and operating controls for each of the remedial processes to optimize performance and minimize emissions
- Isolation of the various remedial activities from populated areas

Figure 4-5: Schematic of Alternative 4 (On-Site Treatment, Solidification/Stabilization)
Options A and B



Source: Arthur D. Little, Inc.

Figure 4-6: Schematic of Alternative 4 (On-Site Treatment, Solidification/Stabilization) Options C and D



Source: Arthur D. Little, Inc.

- Assurance that occupational risks to workers are minimized through proper training and adherence to the site Health and Safety Plan

The permanent application of institutional controls to limit access to, and future use of, the ADA would provide long-term and permanent protection of human health and safety with respect to the presence of UXO.

Compliance with ARARs. Alternative 4 would be expected to meet all ARARs, specifically:

The removal of contaminated soils from the ADA would meet chemical-specific ARARs at that area. Subsequent treatment by solidification/stabilization would further increase adherence to ARARs by immobilizing metal contaminants. The degree to which the metal contaminants are immobilized would require confirmation through conducting analyses and TCLP of the treated product. The ability of solidification/stabilization to immobilize organic contaminants is less certain but could be confirmed during the conduct of treatability testing.

The processes involved in Alternative 4 would not be expected to affect protected species present at the UMDA facility, nor affect any off-site designated wetlands.

All actions associated with this alternative can be adequately controlled so that action-specific ARARs can be met. Dust emission sources will be monitored during soil excavation and handling. Disposal of the treated material will be subject to testing to ensure that adequate contaminant immobilization has occurred to conform to requirements under RCRA.

The continued presence of UXO at the surface and in the subsurface would require that institutional controls to restrict access and limit use be maintained.

Long-Term Effectiveness and Permanence. Solidification/stabilization will result in immobilization or containment of the metal contaminants. This will reduce the risks and hazards associated with handling and transporting the material. The treated product will be removed from the site and disposed of in a solid waste landfill, which will provide additional protection over the long-term. The mobility of organic contaminants after solidification is unknown and would require determination during treatability testing.

The permanent application of institutional controls to limit access to, and future use of, the ADA would provide long-term and permanent protection of human health and safety with respect to the presence of UXO.

Reduction of Toxicity, Mobility, or Volume. The solidification/stabilization process considered for use in this alternative will reduce the mobility of metal

contaminants. It is assumed that the mobility of organic contaminants will be reduced; however, the degree to which this is true will require determination by treatability testing. The disposal of the treated material in a suitable solid waste landfill will further reduce the potential for contaminant mobility.

The process will not reduce contaminant toxicity and the total volume of waste requiring disposal will be increased due to the solidification/stabilization process.

Short-Term Effectiveness. Remedial operations will involve activities that present potential risks and hazards to workers. These activities include soil excavation and handling, heavy equipment use, and solidification/stabilization process operation. Despite these risks and hazards, adequate worker protection can be maintained through the adherence to: site safety plans; standard health and safety protective measures; and monitoring guidelines. Worker protection has been demonstrated for solidification/stabilization processes in previous remedial activities. Appropriate dust controls will be used to ensure that effects to the environment are not significant. The isolation of the remedial operations will ensure that the community will be protected from remedial activities including excavation, on-site movement of contaminated materials, and the solidification/stabilization process.

Off-site transport of treated material will present the most significant source of potential exposure to the community. However, the material at this stage is expected to be non-hazardous. In addition, proper equipment for off-site transportation will be used and the material will be covered to prevent release of any of the treated product.

The total time to implement this alternative ranges from 12 months (for Alternatives 4C and 4D) to 15 months (for Alternatives 4A and 4B).

Implementability. The use of soil washing as a pretreatment is an innovative technology and, as such, its demonstrated effectiveness is not as well established as other, less innovative technologies. Although solidification/stabilization has proven capable of immobilizing metal contaminants, treatability studies will be required to provide for a final determination of the feasibility of the process on ADA soils that contain metals and/or organics. The final treated product will require testing to assure that the maximum potential for contaminant immobility is achieved and can be maintained.

With the exception of soil washing, services and materials for all remedial activities involved in this alternative are readily available. As an innovative technology, there are a limited number of firms that have demonstrated soil washing capabilities. There are several firms that supply transportable, turnkey, systems for complete treatment by solidification/stabilization.

Cost. Cost estimates developed for this alternative were based on engineering calculations, vendor estimates, other documented sources, and experience. The cost of implementation of the solidification/stabilization process will be dependent on the results of treatability studies.

A summary of capital and O&M costs for the implementation of the various options of Alternative 4 is presented in Table 4-3. A detailed breakdown of these costs is provided in Appendix C.

4.2.6 Alternative 5: On-Site Treatment by Incineration and Solidification/Stabilization

4.2.6.1 Description of Alternative. The core of this alternative includes the use of two primary technologies to treat contaminated soils at the ADA: incineration and solidification/stabilization. In addition, options are presented that make use of soil washing to reduce the volume of soil to be subjected to the primary treatment technologies. Clearance of UXO will be performed as necessary to permit excavation of contaminated soil.

Rotary kiln incineration is used to treat soils (and/or fines) contaminated with both metals and organic contaminants (pesticides and explosives). A solidification/stabilization process will be used to treat incinerator residues (ash and particulate removed in the air pollution control system) and soils (and/or fines) contaminated with metals only. Once analysis of the treated material has verified the effectiveness of the treatment in meeting established standards, the treated material would be disposed of: (1) off site in a solid waste landfill; (2) on site in the existing active landfill; or (3) on site in a new landfill. Schematics of the integration of the processes and various options associated with this alternative are presented in Figures 4-7 and 4-8.

A discussion of the soil washing process is provided in Section 4.2.1.4, Soil Washing to Reduce Contaminated Soil Volume. The solidification/stabilization process is described in Section 4.2.1.5, Solidification/Stabilization. The incineration process is described below.

Incineration. Based on an economic analysis performed for the Army, the use of a transportable incinerator as opposed to a field erected incinerator is generally more cost effective at sites with less than 130,000 yd^3 of soil to be treated[49]. Since transportable rotary kiln incinerators have been used successfully in full-scale remediations of explosive-contaminated soil at two Army installations, such a system will form the basis of the incineration portion of this alternative.

Transportable incineration systems are available in a range of sizes with varying feed rates. This analysis will assume that a transportable unit with a nominal feed rate of 4 tons/hr will be used.

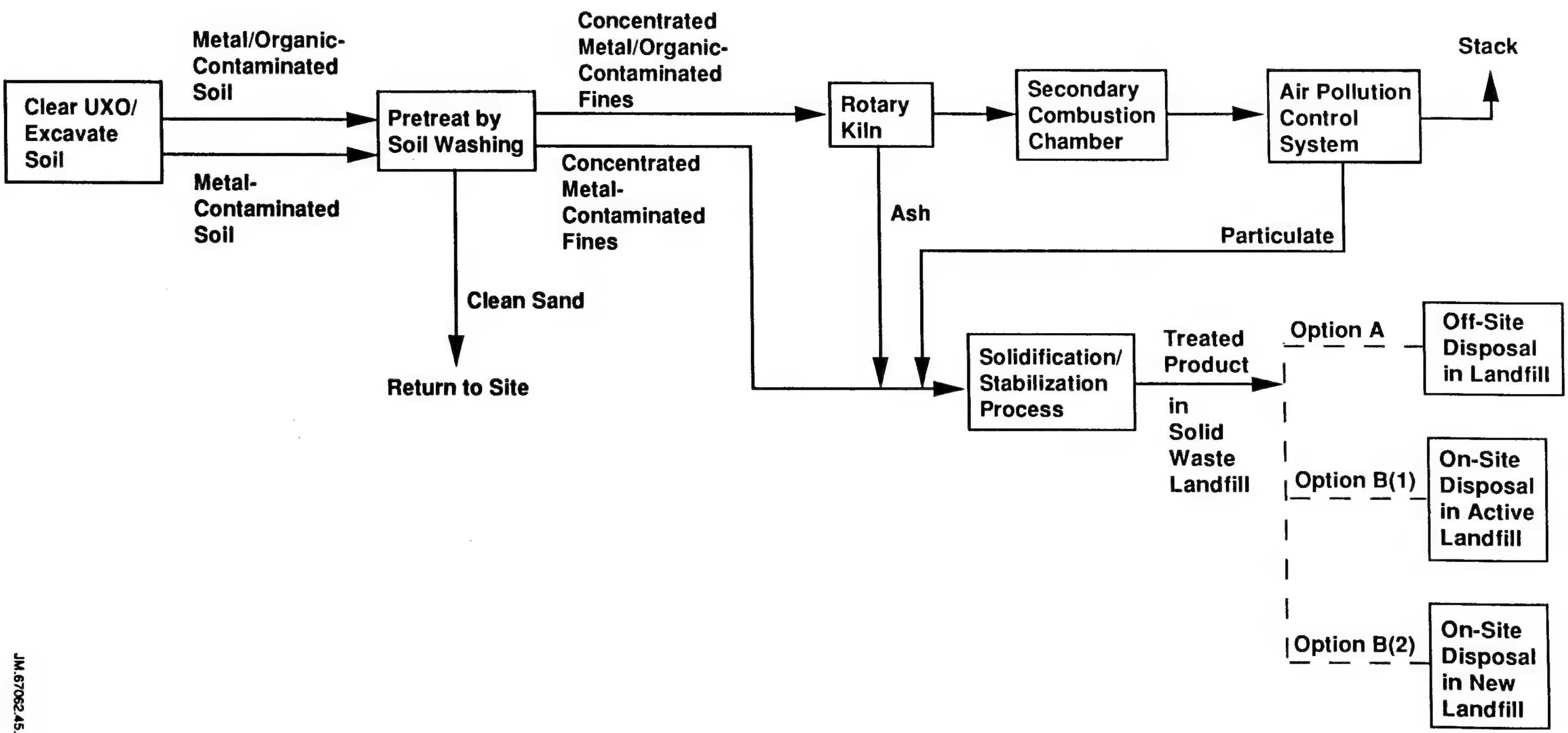
Table 4-3: Alternative 4: On-Site Treatment - Solidification/Stabilization

Element	Alternative Option (1993 Dollars)					
	4A	4B(1)	4B(2)	4C	4D(1)	4D(2)
Capital Cost						
Clear UXO/Excavate Soil	654,000	654,000	654,000	654,000	654,000	654,000
Haul/Stockpile Soil	182,000	182,000	182,000	182,000	182,000	182,000
Soil Washing	669,000	669,000	669,000	0	0	0
Solidification/Stabilization	92,000	92,000	92,000	181,000	181,000	181,000
Off-Site Landfill	503,000			2,512,000		
On-Site Landfill - Active		31,000			157,000	
On-Site Landfill - New			1,331,000			1,457,000
Site Reclamation	272,000	272,000	272,000	272,000	272,000	272,000
Contingency	593,000	475,000	800,000	950,000	361,000	686,000
Total Capital	$2,965,000	$2,380,000	$4,000,000	$4,751,000	$1,807,000	$3,432,000
O&M Cost						
Soil Washing	504,000	504,000	504,000	0	0	0
Solidification/Stabilization	448,000	448,000	448,000	2,033,000	2,033,000	2,033,000
Five Year Review		6,400	6,400		6,400	6,400
Contingency	238,000	239,600	239,600	508,000	509,600	509,600
Total O&M	$1,190,000	$1,198,000	$1,198,000	$2,541,000	$2,549,000	$2,549,000
Remedial Design/Planning	$416,000	$358,000	$520,000	$729,000	$436,000	$598,000
Total Cost	**$4,571,000**	**$3,936,000**	**$5,718,000**	**$8,021,000**	**$4,792,000**	**$6,579,000**
Treatment Cost per CY	**140**	**120**	**175**	**245**	**147**	**201**

Note: Costs are based on cleanup to Residential 1x10-6 level

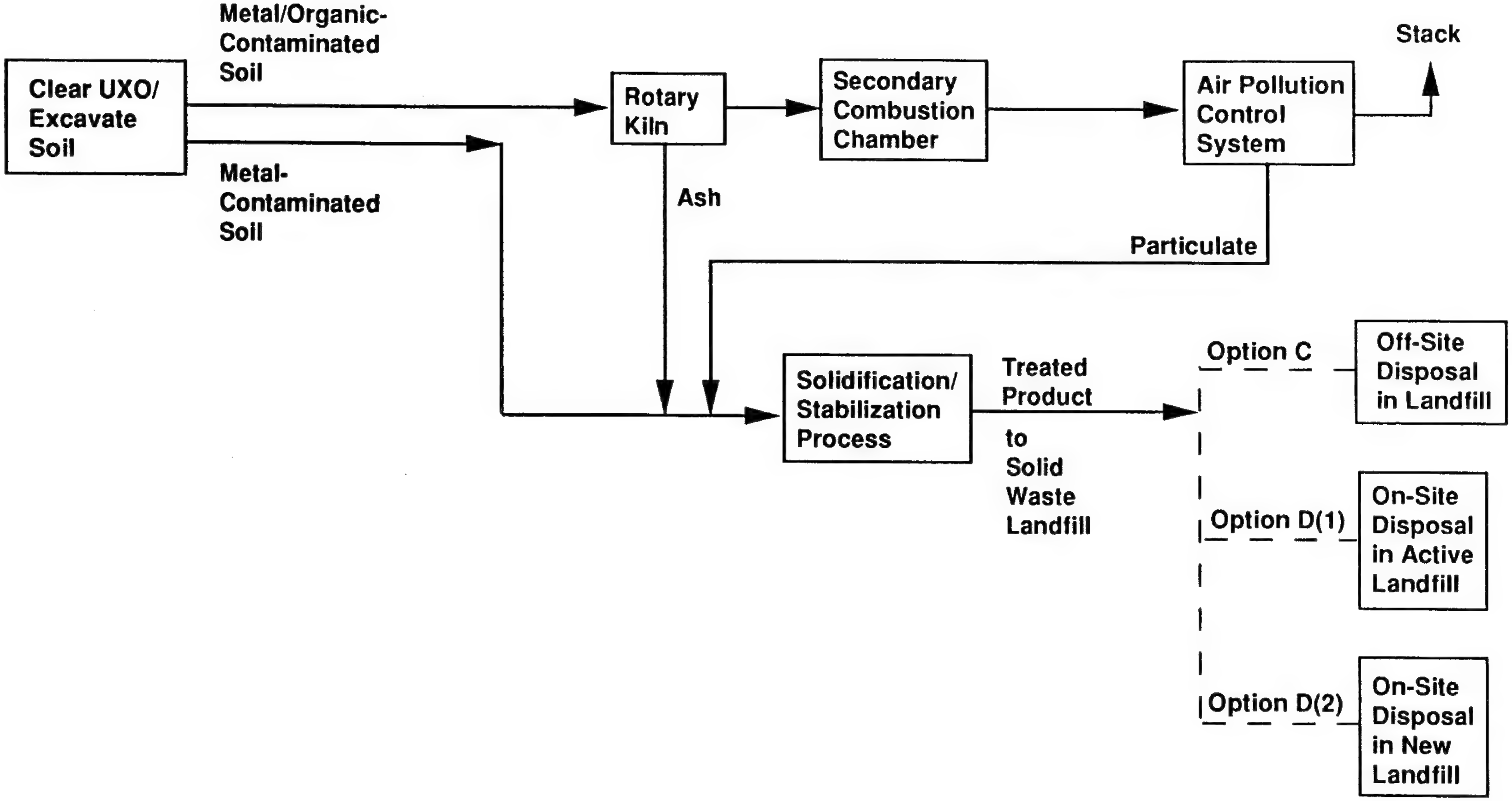
Source: Arthur D. Little, Inc.

Figure 4-7: Schematic of Alternative 5 (On-Site Treatment: Incineration and Solidification/Stabilization) Options A and B



Source: Arthur D. Little, Inc.

Figure 4-8: Schematic of Alternative 5 (On-Site Treatment: Incineration and Solidification/Stabilization) Options C and D



Source: Arthur D. Little, Inc.

The transportable incineration system consists of the following elements:

- Feed system
- Incineration system including a primary chamber (kiln) and a secondary chamber(afterburner)
- Air pollution control system
- Ash collection and handling system

Feed System. Once excavated, the contaminated soil would be placed on a temporary storage pad in the feed staging area. The stockpiled soil would be covered to protect it from precipitation and to prevent its dispersion by wind.

Large rocks and debris would be screened as necessary to preclude damage to the incinerator equipment. Removed rocks or debris would be washed with water to remove any contaminated soil. The volume of washwater generated in this manner is expected to be very low compared to the total volume of incinerator feed, and may therefore be incorporated into the feed with little or no impact on the incineration process.

From the storage pad, the soil would be staged by bulk loading equipment to the incinerator feed area. Since explosives will be present in the feed material, care will be required to eliminate any potential for accumulation or confinement of explosives. This analysis assumes a representative feed system consisting of a metered live bottom hopper; a screw or belt conveyor to transfer the soil from the hopper to the kiln feed system; and a screw or belt conveyor to feed the soil into the kiln.

Incineration System. The primary chamber of the incineration system is the rotary kiln, a rotating, refractory-lined, cylindrical vessel mounted at a slight incline to the horizontal.

The kilns are designed to provide a sufficient residence time to effectively treat the soil. Design factors that specify the residence time include the soil feed rate, kiln rotation rate, and the physical dimensions of the kiln.

The kiln is typically designed for steady-state operation at 1,200°F to 1,800°F. A control system is typically used to automatically maintain primary combustion chamber temperatures within the design range for the particular waste to be treated. A minimum of 100 percent excess air is typical.

The secondary chamber, or afterburner, is a stationary, refractory-lined cylinder. The afterburner design temperatures are higher than those for the kiln, in a range of 1,700 to 2,400 °F. As with the kiln, temperatures in the secondary chamber are controlled automatically. A minimum of 100 percent excess air is usually input to the secondary chamber. Hot gases from the secondary chamber are typically quenched to reduce their temperature prior to further treatment.

Air Pollution Control (APC) System. The incinerator APC system is composed of wet and/or dry scrubbing processes designed to remove products of incomplete combustion, particulates, and acid gases from the flue gas exiting the secondary combustion chamber.

An example of a wet scrubbing system is a venturi scrubber charged with lime or caustic and water solutions. When the contaminants to be removed are nonhalogenated, these systems are typically designed so that the aqueous wastes from the scrubber can be neutralized, filtered, and recycled, thereby minimizing or eliminating wastewater discharges A dry scrubbing system often uses a fabric filter to catch solids and particulate.

It is assumed that any incinerator selected to remediate the soils at the ADA would be equipped with an APC system that would meet local, state, and federal air emissions standards.

Ash Handling and Collection System. The solids that exit the primary and secondary combustion chambers are referred to as ash. The ash is typically collected using a wet ash system in which the hot ash exiting the chambers is quenched with water. Excess water may be recycled to minimize wastewater discharges.

Since all of the contaminated soil contains metals, the ash (including solids from the kiln and particulates from the APC system) will be subjected to solidification/stabilization prior to final disposition.

Site Suitability. The selection of the incineration site would be based on the following:

- The site needs to contain sufficient land area to provide a concentric ring of unoccupied space as a buffer zone between the excavation and incineration areas, and the nearest area of human activity.
- Access roads must be available and capable of supporting the 60,000 lb incinerator trailers and heavy earthmoving equipment.
- Accessibility to the waste feed material must be direct and unencumbered.

Temporary covers would be provided for the contaminated soil and the treated soil stockpiled in the holding area.

Based on the above, the total area requirements for the 4 ton per hour incineration system would be approximately 87,000 ft^2 (2 acres).

In addition to the area actually required for the incineration system, access roads would be required to connect the treatment area with existing roads.

Utilities. Utility requirements for operation of the incineration system described above include:

- A continuous water supply to furnish charge and makeup water to the scrubber system. Evaporative losses are assumed to be approximately 70 gpm. For the purposes of analysis, it is assumed that this water will be available from installation sources. However, if supplies at the treatment site are insufficient, an alternate supply (from on or off the installation) will be required.

- Electrical service of 2,000 kVA, 480 V, and 3 phases is required as the power source for the primary combustion chamber, fans and pumps. In addition, the operation of ancillary operation and support systems will require 15 amp, 120-V, 1-phase service. For the purposes of this analysis, it is assumed that these electrical requirements can be met on the installation.

- Propane equivalent to about 4 million BTU/hr. This will have to be brought onto the site as it is unavailable at the installation.

- Water treatment chemicals, as required.

- Fuel oil for feed heating value improvement, as necessary.

Personnel. The total number of operating personnel required for such a transportable incineration system is 30 to 35. These numbers include process operators, supervisors including a shift foreman, a maintenance supervisor, construction operators (as required), administrative staff and a project manager. Operations are conducted in 2 or 3 shifts, 24 hours per day, 7 days per week.

Performance Testing. Waste characterization and treatability testing are necessary to establish the suitability of the contaminated soil feed and the range of recommended operating parameters for the incineration system. This will ensure optimum incinerator performance to maintain regulatory compliance. Test phases required include:

- Laboratory analysis of waste feed. Required to evaluate physical and chemical properties critical to the operation of the incineration system (including feed preparation, feed to incinerator, incineration, air pollution control, and residue management). Such properties include density, moisture content, heating value, ash content, particle size, organic and inorganic species identification and quantification.

- Trial burn in accordance with regulatory requirements to ensure that required operating and emission standards are attainable and maintained.

Implementation and Treatment Time. For the purpose of this analysis, it is assumed that one year is required to complete all preparations (including procurement) prior to mobilizing the incinerator system on-site. A transportable system will require 3 to 8 weeks to mobilize[42].

The time required to conduct and analyze trial burns will be dependent on the specific regulatory requirements and, in some cases, initial results. A typical RCRA trial burn would include three 4-hour burns. For the purposes of this analysis, it is assumed that the entire trial burn period will require approximately four weeks; this includes planning, preparing, conducting the trial burns and analyzing the results.

Integration of Processes. For the purposes of this analysis, it is assumed that incineration of the explosive and pesticide contaminated soil will be completed prior to the startup of the solidification/stabilization process. By staging the operations in this manner, operation of the solidification/stabilization process can be conducted independently of incineration, allowing for a continuity of feed to the process.

Procurement, site preparation, and treatability testing required for the solidification/stabilization process can occur during the time of operation of the incinerator.

4.2.6.2 NCP Criteria Analysis. The results of an evaluation of Alternative 5 with respect to the screening criteria described in Section 4.1, CERCLA Evaluation Criteria, are provided below.

Overall Protection of Human Health and Environment. This alternative would provide for overall protection of human health and the environment and meet the Remedial Action Objectives by destroying or immobilizing the contaminants of concern. Incineration of the organic-contaminated soil would result in at least a 99.99 percent reduction in contaminants with final concentrations below detection limits. Solidification/stabilization of metals-contaminated soil and incinerator residues would result in immobilization of metals. The treated product will be removed to a solid waste landfill, which will provide for continued protection of human health and environment.

Protection of human health and the environment during remediation would be achieved by:

- Adherence to design and operating controls for each of the remedial processes to optimize performance and minimize emissions
- Isolation of the various remedial activities from populated areas
- Assurance that occupational risks to workers are minimized through proper training and adherence to the site Health and Safety Plan

The permanent application of institutional controls to limit access to, and future use of, the ADA would provide long-term and permanent protection of human health and safety with respect to the presence of UXO.

Compliance with ARARs. Alternative 5 would be expected to meet all ARARs. Removal of contaminated soils from the ADA will allow chemical-specific ARARs to be met at that area. Furthermore, incineration and solidification/stabilization would be expected to meet the requirements for reduction of contaminants to background levels, whether it be by contaminant destruction (incineration) or immobilization (solidification/stabilization). This would require confirmation through conducting analyses and TCLP with the resulting product from the solidification/stabilization process.

The processes involved in Alternative 5 would not be expected to affect protected species present at the UMDA facility, nor affect any off-site designated wetlands.

Incineration has been proven for the destruction of explosives and pesticides. Given the relatively low concentrations of these contaminants in ADA soils, it is expected that the treatment standards can be met. Air emissions from all operations involved in the remediation are expected to meet their respective ARARs providing that operating and control procedures are maintained in accordance with established guidelines. Monitoring of emissions from the incinerator stack will be conducted to ensure compliance.

The continued presence of UXO at the surface and in the subsurface would require that institutional controls to restrict access and limit use be maintained.

Long-Term Effectiveness and Permanence. Incineration of organic-contaminated soil has proven successful in meeting required process efficiencies and performance specifications. The organic contaminants are destroyed in incineration and therefore, represent no short or long-term hazards. Residues from the incineration process are further treated to immobilize metal contaminants, increasing the assurance that the incinerated material poses no risks or hazards from any residual organic contaminants. All treated materials and residues are removed from the site so no associated risks will remain at the site.

Solidification/stabilization will result in immobilization or containment of the metal contaminants in soil and incinerator residues. This will reduce the risks and hazards associated with handling and transporting the material. The treated product will be removed from the site and disposed of in a suitable solid waste landfill, which will provide additional protection over the long-term.

The permanent application of institutional controls to limit access to, and future use of, the ADA would provide long-term and permanent protection of human health and safety with respect to the presence of UXO.

Reduction of Toxicity, Mobility, or Volume. Because incineration of the organic-contaminated soil will result in a destruction of the organic contaminants, a reduction in contaminant toxicity is expected. In addition, incineration will moderately reduce the total volume of organic-contaminated waste.

Solidification/stabilization will reduce the mobility of the metal contaminants. The disposal of the treated material in a suitable solid waste landfill will further reduce the potential for contaminant mobility. The process will not reduce contaminant toxicity and the total volume of waste will be increased due to the solidification/stabilization process.

Short-Term Effectiveness. Remedial operations will involve activities that present potential risks and hazards to workers. These activities include soil excavation and handling, heavy equipment use, incinerator operation, and solidification/stabilization process operation. Despite these risks and hazards, adequate worker protection can be maintained through the adherence to site safety plans, standard health and safety protective measures, and monitoring guidelines. Worker protection has been demonstrated for all of the operations in previous remedial activities.

The isolation of the remedial operations will ensure that the community will be protected from remedial activities including excavation, on-site movement of contaminated materials, and the solidification/stabilization process. This isolation, when combined with adherence to proper operating conditions of the incineration and ancillary air pollution control processes, further assures community protection.

Off-site transport of treated material will present the most significant source of potential exposure to the community. However, the material at this stage is expected to be non-hazardous. In addition, proper equipment for off-site transportation will be used and the material will be covered to prevent release of any of the treated product.

It is estimated that a total implementation time for contaminated soil without pretreatment (Options C and D) will be approximately 20 months. For Options A and B involving pretreatment by soil washing, treatment time is estimated at approximately 24 months.

Implementability. The use of soil washing as a pretreatment is an innovative technology and, as such, its demonstrated effectiveness is not as well established as other, less innovative, technologies. The technical feasibility of the incineration of organic-contaminated soil has been demonstrated and documented. Although solidification/stabilization has proven capable of immobilizing metal contaminants, treatability studies will be required to provide for a final determination of the feasibility of the process on soils and incinerator residues. The final treated product will require extensive testing to assure that the maximum potential for contaminant immobility is achieved and can be maintained.

With the exception of soil washing, services and materials for all remedial activities involved in this alternative are readily available. As an innovative technology, there are a limited number of firms who have demonstrated soil washing capabilities. A number of firms provide capabilities for mobilizing, operating, and demobilizing transportable incinerator systems. An increasing number of firms supply transportable, turnkey, systems for complete treatment by solidification/stabilization.

Cost. Cost estimates developed for this alternative were made based on engineering calculations, vendor estimates, other documented sources, and experience. The cost of implementation of the solidification/stabilization process will be dependent on the results of treatability studies. As a result, associated costs should be considered as preliminary estimates.

A summary of capital and O&M costs for the implementation of the various options of Alternative 5 is presented in Table 4-4. A detailed breakdown of these costs is provided in Appendix C.

4.2.7 Alternative 6: Off-Site Treatment and Disposal

4.2.7.1 Description of Alternative. The implementation of this alternative involves the excavation of soil (as described in Section 4.2.1.3, Soil Excavation), segregation of RCRA hazardous and nonhazardous soils, transportation of these soils off site for the treatment of the hazardous soil and landfill disposal of the nonhazardous soil. Clearance of UXO will conducted as necessary to permit excavation of contaminated soil. A general schematic of this alternative is presented in Figure 4-9.

In this alternative, existing data and additional confirmation sampling and analysis will be used to determine the hazardous characteristics of the soil (with respect to the presence of toxic concentrations of metals, pesticides, or explosives) and allow for segregation of RCRA hazardous and nonhazardous soil. To the maximum extent possible, segregation will occur during excavation with necessary confirmation analyses performed after excavation. If the soils are determined to be nonhazardous, they will be transported off site for disposal at a solid waste landfill facility. If the soils are hazardous, they will be transported off site for treatment at a permitted Treatment, Storage, and Disposal Facility (TSDF). The latter action will require the preparation of manifests for the transport of hazardous material before the soils can be transported off site.

Personnel requirements for the implementation of this alternative are minimal. Personnel will be required to excavate the soil; conduct sampling and analysis of the soil samples; prepare manifests as necessary; and load the excavated soil for transport off site. It is estimated that eight personnel would be required for these activities and each would operate on a one-shift, ten hour per day, five days per week, schedule.

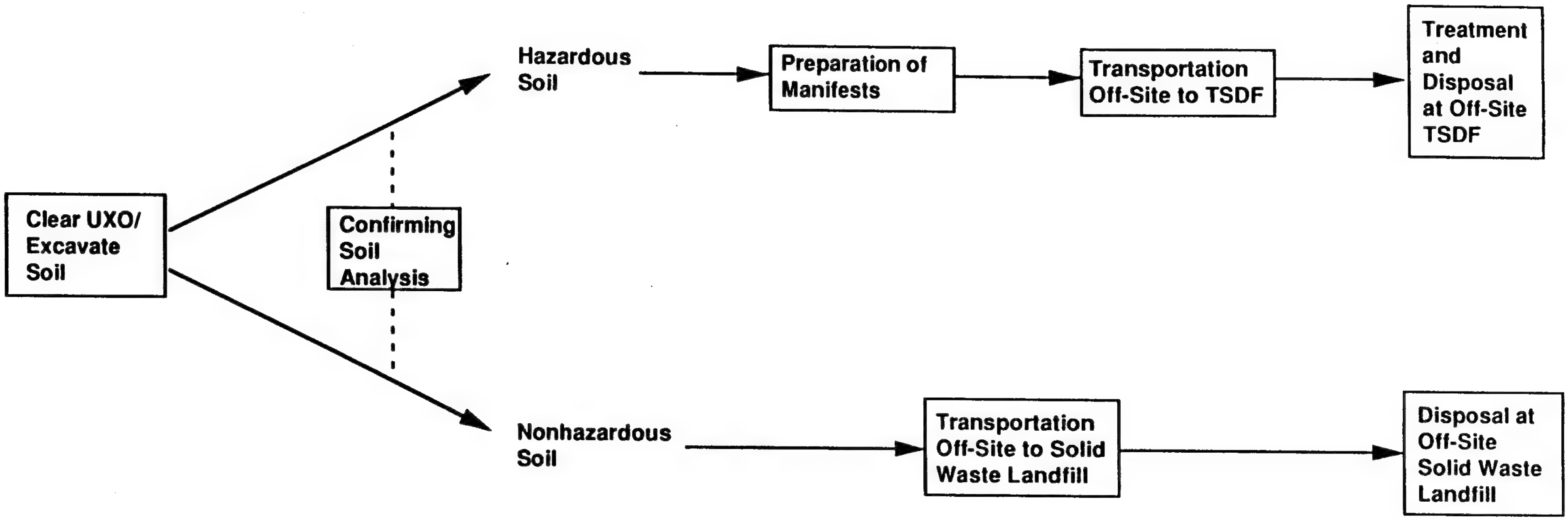
Table 4-4: Alternative 5: On-Site Treatment - Incineration and Solidification/Stabilization

Element	Alternative Option (1993 Dollars)					
	5A	5B(1)	5B(2)	5C	5D(1)	5D(2)
Capital Cost						
Clear UXO/Excavate Soil	654,000	654,000	654,000	654,000	654,000	654,000
Haul/Stockpile Soil	182,000	182,000	182,000	182,000	182,000	182,000
Soil Washing	669,000	669,000	669,000	0	0	0
Incineration	811,000	811,000	811,000	3,256,000	3,256,000	3,256,000
Solidification/Stabilization	89,000	89,000	89,000	166,000	166,000	166,000
Off-Site Landfill	435,000			2,173,000		
On-Site Landfill - Active		27,000			136,000	
On-Site Landfill - New			1,327,000			1,436,000
Site Reclamation	272,000	272,000	272,000	272,000	272,000	272,000
Contingency	778,000	676,000	1,001,000	1,676,000	1,166,000	1,491,000
Total Capital	$3,890,000	$3,380,000	$5,005,000	$8,379,000	$5,832,000	$7,457,000
O&M Cost						
Soil Washing	504,000	504,000	504,000	0		
Incineration	1,282,000	1,282,000	1,282,000	5,049,000	5,049,000	5,049,000
Solidification/Stabilization	398,000	398,000	398,000	1,770,000	1,770,000	1,770,000
Five Year Review		6,400	6,400		6,400	6,400
Contingency	546,000	547,600	547,600	1,705,000	1,705,600	1,705,600
Total O&M	$2,730,000	$2,738,000	$2,738,000	$8,524,000	$8,531,000	$8,531,000
Remedial Design/Planning	$662,000	$612,000	$774,000	$1,690,000	$1,324,000	$1,599,000
Total Cost	$7,282,000	$6,730,000	$8,517,000	$18,593,000	$15,687,000	$17,587,000
Treatment Cost per CY	223	206	260	569	480	538

Note: Costs are based on cleanup to Residential, 1x10-6 level

Source: Arthur D. Little, Inc.

Figure 4-9: Schematic of Alternative 6 (Off-Site Treatment and Disposal)



(TSDF - Hazardous Waste Treatment, Storage, Disposal Facility)

Source: Arthur D. Little, Inc.

Personnel exposed to contaminated soil are subject to Occupational Safety and Health Administration (OSHA) requirements for hazardous waste site operations (29 CFR 1910.120), including: requirements for personal protective equipment as dictated by the specific site conditions and contaminants; physical examinations; and hazardous waste site training.

4.2.7.2 NCP Criteria Analysis. The degree to which this alternative satisfies the seven threshold and primary balancing criteria of the NCP is discussed in the following sections.

Overall Protection of Human Health and the Environment. The implementation of Alternative 6 would provide for overall protection of human health and the environment at and meet the remedial action objectives by removing contaminated soil that is the source of unacceptable risks and hazards from UMDA.

Treatment of some of the contaminated soil off site will enhance the protection of human health and the environment; however, the lack of treatment of the balance of the contaminated soil will not. As a result of lack of treatment, no reduction in toxicity or volume of contaminants will occur. Furthermore, this lack of treatment does not satisfy statutory preference for treatment as a principal element of a remedial activity.

A reduction in mobility of contaminants will be realized by the disposal of nonhazardous soil and treatment products in a properly designed and constructed landfill.

Near-term protection of the public health and the environment during remediation would be achieved directly by using specific design and operating controls to minimize fugitive dust emissions. Indirect protection would also be afforded by the distance from the ADA to populated areas.

Occupational risks to on-site workers are expected to be minimized through the use of specific operating controls and procedures and appropriate training. Occupational risks would be addressed in the project Health and Safety Plan.

The permanent application of institutional controls to limit access to, and future use of, the ADA would provide long-term and permanent protection of human health and safety with respect to the presence of UXO.

Compliance with ARARs. This alternative will comply with the health- and risk-based chemical-specific ARARs because all contaminated soil not in compliance with these ARARs will be removed from the ADA. Soil exhibiting the toxicity characteristic will be treated in accordance with RCRA requirements.

This alternative would comply with location-specific ARARs as it is not expected that protected species present at UMDA would be affected nor would any off-site designated wetlands be impacted.

This alternative will involve the removal of contaminated soil from the ADA in accordance with all regulatory and other institutional guidelines. Excavation and handling of soils will be conducted in accordance with guidelines for dust suppression, thus eliminating the threat of atmospheric dispersion of fugitive emissions to downwind receptors. Manifests will be prepared for the off-site treatment of hazardous soils.

The continued presence of UXO at the surface and in the subsurface would require that institutional controls to restrict access and limit use be maintained.

Long-Term Effectiveness and Permanence. Because contaminated soil would be removed from the ADA, there will be no residual risks at the area. The areas where soil is removed will be refilled and restored to surrounding conditions following remediation. A five-year review will not be required following contaminated soil removal at the ADA as long as unrestricted cleanup levels are achieved.

Once the contaminated soil has been removed from the ADA and UMDA, the soil characterized as nonhazardous will be disposed of in a solid waste landfill. It is expected that short- and long-term uncertainties associated with such a disposal will be minimal. Soil characterized as hazardous will be treated accordingly at a TSDF that is permitted to ensure the maximum protection of human health and the environment.

Reduction of Toxicity, Mobility, and Volume. This alternative results in the reduction of the volume of contaminated soils present at the ADA; however, the removal of these soils does not itself constitute a reduction in volume of contaminated media. Only those soils that exhibit characteristics of a hazardous waste will be treated. It is expected that treatment of these soils would result in a reduction of mobility of contaminants. Such treatment is unlikely to significantly reduce the toxicity of metal contaminants.

A certain volume of the contaminated soil will not be treated. No reduction in toxicity or volume will occur. Furthermore, this lack of treatment does not satisfy statutory preference for treatment as a principal element of a remedial activity.

A reduction in mobility of contaminants will be realized by disposal of nonhazardous soil and treatment products in a properly designed and constructed landfill.

Short-Term Effectiveness. The protection of the environment, the surrounding community, and workers during implementation of this alternative can be maintained by applying adequate controls during excavation and by adhering to manifesting requirements and common sense during off-site transport of the contaminated materials.

Additional protection of the environment from adverse impact will be ensured by restoration of the ADA to natural conditions after removal of the contaminated soil.

The implementation of this alternative is expected to be accomplished within a short time. The time to achieve the remedial action objectives is estimated to be approximately 12 months after contracts are in place for the receipt of soil at the solid waste landfill facility and the TSDF.

Implementability. This alternative for site remediation is a demonstrated technique. The alternative has a high level of technical feasibility with no technical difficulties or unknowns expected. Equipment and services required for its implementation are readily available from a number of sources.

The level of administrative-related activities from a permitting standpoint is moderate. However, obtaining the necessary coordinations and approvals for off-site transportation, treatment, and disposal may be a barrier to implementation of the alternative.

Cost. The cost of implementing this alternative will be dependent on a number of factors including the location of the TSDF and the solid waste landfill selected to receive the contaminated soil. A summary of estimated capital and O&M costs associated with this alternative is presented in Table 4-5. A detailed breakdown of costs is provided in Appendix C.

4.2.8 Alternative 7: On-Site Treatment and Disposal

4.2.8.1 Description of Alternative. This alternative involves the on-site treatment of hazardous soil by solidification/stabilization (as discussed in Section 4.2.1.5, Solidification/Stabilization) and the on-site disposal of nonhazardous soils and treatment residues in the existing active landfill or in a new engineered landfill (as discussed in Section 4.2.1.6, On-Site Landfill Disposal of Soil and/or Treatment Residues). Clearance of UXO will be performed as necessary to permit the excavation of contaminated soil. A schematic illustrating the activities of this alternative is presented in Figure 4-10.

In this alternative, existing data and additional confirmation sampling and analysis will be used to determine the hazardous characteristics of the soil (with respect to the presence of toxic concentrations of metals, pesticides, or explosives) and allow for segregation of hazardous and nonhazardous soil. To the maximum extent possible, segregation will occur during excavation with necessary confirmation analyses performed after excavation. If the soils are determined to be nonhazardous, they will be transported on site to the existing active landfill (Option 7A(1)) or to a new engineered landfill to be constructed on site (Option 7A(2)). If the soils are hazardous, they will be treated by

Table 4-5: Alternative 6: Off-Site Treatment and Disposal

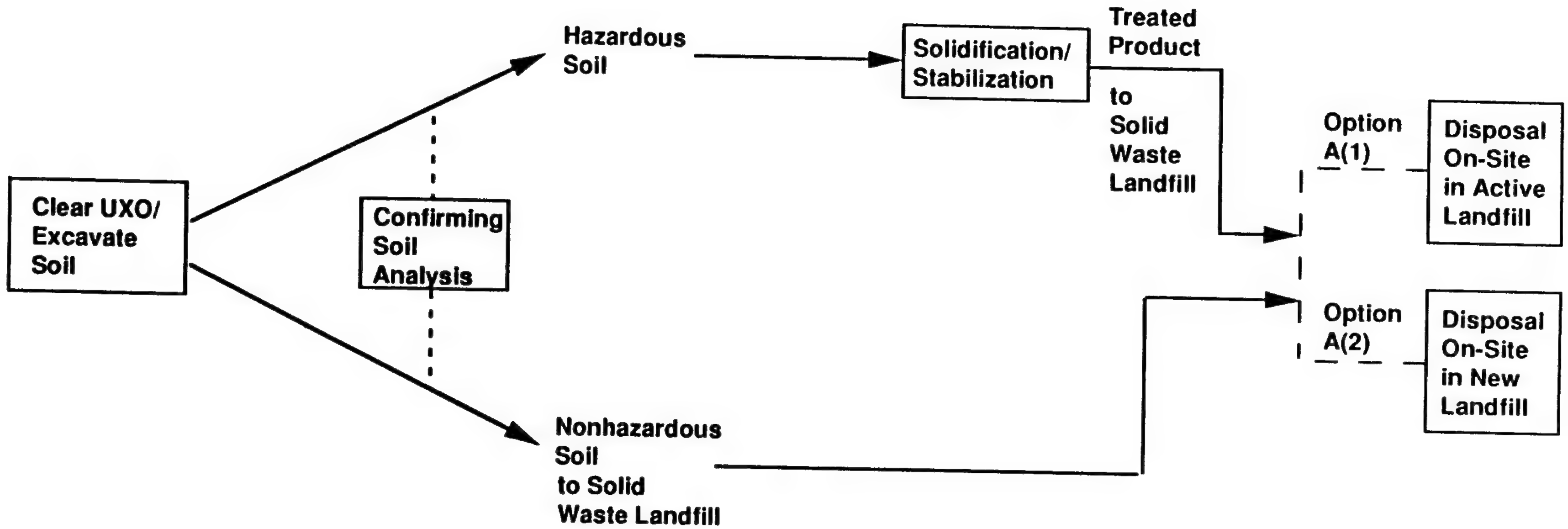
Element	Alternative 6 (1993 Dollars)
Capital Cost	
Clear UXO/Excavate Soil	654,000
Characterize Soil	64,000
Stockpile/Cover Soils	182,000
Haul Soils Off Site	459,000
Treat Hazardous Soils Off Site (1)	2,616,000
Off-Site Disposal of Nonhazardous Soils (1)	916,000
Site Restoration	272,000
Contingency	1,291,000
Total Capital	6,460,000
O&M Cost	
There are no O&M costs associated with this Alternative	0
Total O&M	0
Remedial Design/Planning	646,000
Total Cost	**7,106,000**
Treatment Cost per CY	**217**

Note: Costs are based on cleanup to Residential, 1x10-6 level

(1) Assumes that 50% of soil is characterized as hazardous; 50% of soil is characterized as nonhazardous

Source: Arthur D. Little, Inc.

Figure 4-10: Schematic of Alternative 7 (On-Site Treatment and Disposal)



Source: Arthur D. Little, Inc.

solidification/stabilization to render them nonhazardous. Treatment residuals will be disposed of on site in the active landfill (Option 7A(1)) or in a new on-site landfill (Option 7A(2)).

4.2.8.2 NCP Criteria Analysis. The degree to which this alternative satisfies the seven threshold and primary balancing criteria of the NCP is discussed in the following sections.

Overall Protection of Human Health and the Environment. The implementation of Alternative 7 would provide for overall protection of human health and the environment and meet the remedial action objectives by removing contaminated soil that is the source of unacceptable risks and hazards from the ADA.

Treatment of some of the contaminated soil on site will enhance the protection of human health and the environment; however, the lack of treatment of the balance of the contaminated soil will not. As a result of lack of treatment, no reduction in toxicity or volume of contaminants will occur. Furthermore, lack of treatment does not satisfy statutory preference for treatment as a principal element of a remedial activity.

A reduction in mobility of contaminants will be realized by the disposal of nonhazardous soil and treatment products in a properly designed and constructed landfill.

Near-term protection of the public health and the environment during remediation would be achieved directly by using specific design and operating controls to minimize fugitive dust emissions during excavation and soil handling. Indirect protection would also be afforded by the distance from the ADA to populated areas.

Occupational risks to on-site workers are expected to be minimized through the use of specific operating controls and procedures and appropriate training. Occupational risks would be addressed in the project Health and Safety Plan.

The permanent application of institutional controls to limit access to, and future use of, the ADA would provide long-term and permanent protection of human health and safety with respect to the presence of UXO.

Compliance with ARARs. This alternative will comply with the health- and risk-based chemical-specific ARARs because all contaminated soil not in compliance with these ARARs will be removed from the ADA. Soil that exhibits the toxicity characteristic will be treated in accordance with RCRA requirements.

This alternative would comply with location-specific ARARs as it is not expected that protected species present at UMDA would be affected nor would any off-site designated wetlands be impacted.

This alternative will involve the removal the contaminated soil from the ADA in accordance with all regulatory and other institutional guidelines. Excavation and handling of soils will be conducted in accordance with guidelines for dust suppression thus eliminating the threat of atmospheric dispersion of fugitive emissions to downwind receptors.

The continued presence of UXO at the surface and in the subsurface would require that institutional controls to restrict access and limit use be maintained.

Long-Term Effectiveness and Permanence. Because contaminated soil would be removed from the ADA, there will be no residual risks at the area. The areas where soil is removed will be refilled and restored to surrounding conditions following remediation. A five-year review will not be required following contaminated soil removal at the ADA provided that cleanup is to unrestricted levels.

Once the contaminated soil has been removed from the ADA it will be treated if it is determined to be hazardous. The treatment products will be disposed of on site. It is expected that short- and long-term uncertainties associated with such a disposal will be minimal; particularly when compared to leaving the hazardous soils in place. Untreated, nonhazardous contaminated soil will be disposed of without treatment. The short- and long-term uncertainties with the disposal of these untreated materials are expected to be of greater concern and will require monitoring and review.

Reduction of Toxicity, Mobility, and Volume. This alternative results in the reduction of the volume of contaminated soils present at the ADA; however, the removal of these soils does not itself constitute a reduction in volume of contaminated media. Only those soils that exhibit characteristics of a hazardous waste will be treated. It is expected that treatment of these soils would result in a reduction of mobility of contaminants. Since the soil to be treated will contain metal contaminants, such treatment is unlikely to significantly reduce the toxicity of the contaminants.

A certain volume of the contaminated soil will not be treated. No reduction in toxicity or volume will occur. Furthermore, this lack of treatment does not satisfy statutory preference for treatment as a principal element of a remedial activity.

A reduction in mobility of contaminants will be realized by the disposal of nonhazardous soil and treatment products in a properly designed and constructed landfill.

Short-Term Effectiveness. The protection of the environment, the surrounding community, and workers during implementation of this alternative can be maintained by applying adequate controls during excavation and by adhering to manifesting requirements and common sense during off-site transport of the contaminated materials. Additional protection of the environment from adverse impact will be ensured by restoration of the ADA to natural conditions after removal of the contaminated soil.

The implementation of this alternative is expected to be accomplished within a time period of approximately 12 months.

Implementability. Treatment of soil by solidification/stabilization has been demonstrated. Equipment and services required for its implementation are readily available from a number of sources. Disposal of treatment residues in the active landfill or in a new on-site landfill is expected to be implementable. However, the administrative feasibility of disposal of additional quantities of contaminated soil in the active landfill and the construction of a new landfill will require a significant level of on-site and off-site coordination (including permitting).

Cost. A summary of capital and O&M costs associated with this alternative is presented in Table 4-6. A detailed breakdown of costs is provided in Appendix C.

4.3 Comparative Analysis of Alternatives

The comparative analysis of the seven alternatives and options is presented below for each of the NCP evaluation criteria.

4.3.1 Protection of Human Health and the Environment

Alternatives 4 and 5 provide the best potential for effectively protecting human health and the environment. These alternatives provide for the removal of the contaminated soil followed by treatment to destroy and/or immobilize the contaminants. Following treatment, the treated residuals are placed in a landfill that is, or will be, properly maintained, closed, and monitored. Of the various options associated with Alternatives 4 and 5, those that involve the placement of treatment residuals in an on-site landfill (existing active landfill or a new landfill) provide additional protection to human health and the environment by eliminating the off-site transport and disposal of these materials.

Alternatives 6 and 7 provide for a moderate level of protection of human health and the environment as they do provide for the treatment of contaminated soils that exhibit the toxicity characteristic. However, soils that do not exhibit the toxicity characteristic and are thus classified as nonhazardous are disposed of, without treatment, in an off-site landfill. Neither of the alternatives provide for an ultimate reduction in contaminant toxicity or volume. Treatment of hazardous soils and disposal of treatment products and nonhazardous soil in a properly designed and constructed landfill will provide for a reduction in contaminant mobility. Alternative 6 provides increased potential for protection of human health and the environment through on-site treatment and disposal of the contaminated soils thereby eliminating the need for off-site transport, treatment, and disposal.

Table 4-6: Alternative 7: On-Site Treatment and Disposal

Element	Alternative Option (1993 Dollars)	
	7A(1)	7A(2)
Capital Cost		
Clear UXO/Excavate Soil	654,000	654,000
Characterize Soil	64,000	64,000
Stockpile/Cover Excavated Soil	182,000	182,000
Solidification/Stabilization of hazardous soils (1)	125,000	125,000
On-Site Disposal in Active Landfill	144,000	
On-Site Disposal in New Landfill		1,444,000
Site Restoration	272,000	272,000
Contingency	360,000	685,000
Total Capital	$1,801,000	$3,426,000
O&M Cost		
Solidification/Stabilization	1,003,000	1,003,000
Five Year Review	6,400	6,400
Contingency	252,600	252,350
Total O&M	$1,262,000	$1,270,000
Remedial Design/Planning	$306,000	$470,000
Total Cost	**$3,369,000**	**$5,166,000**
Treatment Cost per CY	**103**	**158**

Note: Costs are based on cleanup to Residential, 1x10-6 level

(1) Assumes that 50% of soil is characterized as hazardous; 50% of soil is characterized as nonhazardous

Source: Arthur D. Little, Inc.

Alternative 3 will achieve protection of human health and the environment by the use of soil covers or caps placed over the contaminated soils to prevent the dispersion of contaminants in windborne dust and to reduce infiltration. The use of institutional measures to control access and future use activities will further provide a level of protection. However, this alternative does not remove the source of chemical contamination and does not provide for the reduction of toxicity or volume of contaminants. This alternative requires the long-term and permanent application of monitoring, security, and institutional controls.

Alternative 2 will provide for a reduction of risks and hazards associated with the presence of UXO at the ADA. However, the lack of action taken for the chemical contamination of soil would not provide for increased protection human health or the environment with respect to preventing exposure to contaminants or the further spread of these contaminants as windborne dust.

Alternative 1 would not provide any protection of human health and the environment over the current state of the ADA. Risks and hazards associated with the presence of UXO would remain and nothing would be done to prevent exposure to contaminants or the further spread of these contaminants as windborne dust.

4.3.2 Compliance with ARARs

Alternatives 4, 5, 6, and 7 would meet chemical- and action-specific ARARs through a course of:

- Removal of UXO to the degree necessary to perform the remedial activities
- Removal of contaminated soil from the ADA, thereby reducing residual risks to required levels
- Treatment to destroy organic contaminants (Alternative 5) or reduce the mobility of metal contaminants (Alternatives 4, 5, 6, and 7) resulting in residuals that conform to regulatory standards

Alternative 2 will provide for the clearance of UXO to the degree that will allow for limited use of the ADA as specified in the TBC proposed standards for clearance.

Alternatives 1 and 2 will not meet chemical-specific ARARs that require a reduction in the levels of contaminants in the soil. Alternative 3 will result in the prevention of exposure to unacceptable levels of contamination, but will not reduce the level of contaminants in soil.

4.3.3 Long-Term Effectiveness

Alternatives 4, 5, 6, and 7 provide for the varying degrees of treatment of contaminated soil. Uncertainties associated with long-term effectiveness arise due to the ultimate

disposal of treatment residues and/or nonhazardous contaminated soil. Alternatives 4 and 5 provide for the lesser degree of uncertainty with respect to ultimate disposal as all contaminated soil is treated and only treatment residues are disposed of. Alternatives 6 and 7 only provide for the treatment of hazardous soil resulting in the need for landfill disposal of nontreated, nonhazardous soil in addition to treatment residues.

Alternative 3 provides only limited assurance that the actions taken will be effective over the long term. Soil covers and caps used to contain contamination are typically not considered to be either long-term or permanent solutions to contamination or exposure. The long-term effectiveness of their use at the ADA, however, is enhanced through the application of access and future use controls.

Alternative 2 would provide for long-term effectiveness with respect to the removal of UXO; however, this alternative does not provide for any actions to be taken with respect to contaminated soil.

Alternative 1 does not provide for any actions to be taken and, as such, there is no application of Alternative 1 to this criterion.

4.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 3, 4, 5, 6, and 7 provide for various degrees of reducing the toxicity, mobility, and/or volume of contaminants through treatment. Alternative 3 will provide a reduction in contaminant mobility, but will not reduce contaminant toxicity or volume. Alternative 4 will result in the immobilization of contaminants (to be demonstrated in treatability testing), however it will not result in a reduction of contaminant toxicity. By employing the option of soil washing to initially reduce the volume of contaminated soil, this alternative will ultimately result in the reduction of contaminant volume. If the soil washing option is not pursued, the total volume will increase as a result of the solidification/stabilization process. The implementation of Alternative 5 will result in the destruction of organic contaminants and the immobilization of metal contaminants (to be demonstrated in treatability testing). As with Alternative 4, the use of soil washing as a pretreatment will result in a decrease in the volume of contaminants. Further decreases in contaminant volume will be achieved in Alternative 5 through the incineration of material containing organic contaminants.

Alternatives 6 and 7 do not provide for a reduction in toxicity or volume of contaminants but do provide a reduction in the mobility of contaminants. These alternatives provide only for the treatment of contaminated soil that is classified as hazardous. Other contaminated nonhazardous soils are untreated. An additional reduction in contaminant mobility may be achieved through the disposal of treatment residues and untreated soil in controlled landfills.

The only means of reducing contaminant toxicity or volume through the application of Alternatives 1, 2, and 3 is through natural attenuation of the contaminants over time. Due

to the persistent nature of the contaminants, there is little possibility that natural attenuation would ever be complete.

4.3.5 Short-Term Effectiveness

Operations associated with Alternatives 2 and 3 are not expected to increase the risks to the community since no contaminants will be released to the environment. Risks to workers involved in implementing the alternative would be minimized through the use of engineering controls and personal protective equipment. Risks and hazards associated with UXO clearance will be minimized through the use of trained explosive safety personnel and maintaining adequate distances between clearance operations and other activities. The maximum effectiveness of Alternative 2 would be achieved in a short period of time ranging from 4 to 20 months depending on the degree of UXO clearance selected. Alternative 3 would require approximately 15 months.

Alternatives 4, 5, 6, and 7 provide the potential for risks to workers and the community as they involve the removal, handling, treatment, and transport of contaminated soil and treatment residues. Options of Alternatives 4, 5, and 6 that involve the removal of treatment residues and contaminated soil off site for treatment or disposal provide the greatest risk to the community; however, these risks can be minimized through the application of appropriate controls. Risks to workers involved in the various activities of Alternatives 4, 5, 6, and 7 will be minimized through the application of proper engineering controls and the use of personal protective equipment. The maximum effectiveness of Alternatives 4, 5, 6, and 7 can be achieved within approximately two years of their initiation.

4.3.6 Implementability

The technical feasibility of Alternatives 2 and 3 have been demonstrated. Soil covers and caps have been used for years to provide for containment of a variety of material. UXO clearance has been practiced for many years at current and former military sites. Materials and services required to implement these alternatives are readily available from a number of sources.

Most of the activities involved in Alternatives 4, 5, 6, and 7 (e.g., soil excavation, soil handling, transport, treatment by solidification/stabilization and/or incineration, and landfill disposal of treatment residues and/or soil) have been demonstrated in remedial applications. Services and materials are readily available for their performance. The use of solidification/stabilization will require that treatability testing be conducted to ensure that it can meet treatment requirements. Options of Alternatives 4 and 5 that involve the use of soil washing as a pretreatment to reduce the volume of contaminated soil introduce a greater degree of uncertainty with respect to technical feasibility and the availability of services and materials. The soil washing process to be used is considered an innovative technology and, as such, there have been fewer demonstrations of its use and the materials and services required for its implementation may be less readily available.

Uncertainties associated with the administrative feasibility of Alternatives 4, 5, 6, and 7 center on those options that involve the transport of treated and untreated materials off site. Adequate coordination between on-site and off-site personnel will be required to ensure that transportation is performed under compliance and with minimum risk of potential on-site and off-site exposure to contamination. Additional administrative compliance will be required with respect to the operation of the on-site incinerator included as part of Alternative 5.

4.3.7 Cost

The capital and operating costs for each of the alternatives and options are presented in Table 4-7. In addition, a unit volume cost is provided for those alternatives and options that involve treatment of the contaminated soil.

An additional cost presentation has been prepared to reflect the potential for reduction in costs associated with the remedial alternatives and options as a result of cleanup to levels that will permit light industrial use with residual risks imposed by soil of $1x10^{-6}$ and $1x10^{-5}$ and military use with residual risks imposed by soil of $1x10^{-6}$. These costs are provided in Table 4-8. For reference, the volumes of affected soil for each of these cleanup levels are provided (refer to Section 2.3.2, Estimated Areas and Volumes of Contaminated Media Requiring Remediation).

4.3.8 Remediation of Selected Sites

Following a discussion between the Army and regulatory agencies, there appear to be six sites that require remediation based on risk and hazard levels[50]. These sites were identified as having risks greater than $1x10^{-4}$ (residential) or hazard quotients in excess of 1 (residential). An analysis of the remediation of these sites was conducted.

The sites addressed in this analysis include Sites 15, 16, 17, 19, 31, and 32-II. Residential risks and hazards of these sites are presented in Table 4-9. This table also presents the affected areas and volumes requiring remediation to residential, light industrial, and military future use levels.

Costs developed for each of the remedial alternatives applied to these sites are presented in Table 4-10.

Table 4-7: Summary of Cost of Alternatives

Alternative	Capital Cost ($)	O&M Cost ($)	Remedial Design/Planning ($)	Total Cost ($)	Cost per Unit of Soil ($/cu yd)
1	0	0	0	0	NA
2A	1,094,000	8,000	110,000	1,212,000	NA
2B	6,560,000	8,000	657,000	7,225,000	NA
2C	13,781,000	8,000	1,379,000	15,168,000	NA
3A	395,000	8,000	40,000	443,000	NA
3B	589,000	8,000	60,000	657,000	NA
4A	2,965,000	1,190,000	416,000	4,571,000	140
4B(1)	2,380,000	1,198,000	358,000	3,936,000	120
4B(2)	4,000,000	1,198,000	520,000	5,718,000	175
4C	4,751,000	2,541,000	729,000	8,021,000	245
4D(1)	1,807,000	2,549,000	436,000	4,792,000	147
4D(2)	3,432,000	2,549,000	598,000	6,579,000	201
5A	3,890,000	2,730,000	662,000	7,282,000	223
5B(1)	3,380,000	2,738,000	612,000	6,730,000	206
5B(2)	5,005,000	2,738,000	774,000	8,517,000	260
5C	8,379,000	8,524,000	1,690,000	18,593,000	569
5D(1)	5,832,000	8,531,000	1,324,000	15,687,000	480
5D(2)	7,457,000	8,531,000	1,599,000	17,587,000	538
6	6,460,000	0	646,000	7,106,000	217
7A(1)	1,801,000	1,262,000	306,000	3,369,000	103
7A(2)	3,426,000	1,270,000	470,000	5,166,000	158

Note: Costs are based on cleanup to Residential, 1x10-6 level

NA – Not Applicable (total cost is independent of soil volume)

Source: Arthur D. Little, Inc.

Table 4-8: Comparison of Costs for Different Cleanup Levels Based on Risk Scenarios

Alter-native	Residential, 1 x 10-6				Light Industrial, 1 x 10-6				Light Industrial, 1 x 10-5				Military, 1 x 10-6			
	Capital ($000)	O&M ($000)	Design/ Planning ($000)	Total ($000)	Capital ($000)	O&M ($000)	Design/ Planning ($000)	Total ($000)	Capital ($000)	O&M ($000)	Design/ Planning ($000)	Total ($000)	Capital ($000)	O&M ($000)	Design/ Planning ($000)	Total ($000)
1	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**
2A	1094	8	110	**1212**	1094	8	110	**1212**	1094	8	110	**1212**	1094	8	110	**1212**
2B	6560	8	657	**7225**	6563	8	657	**7225**	6563	8	657	**7225**	6563	8	657	**7225**
2C	13781	8	1379	**15168**	13781	8	1379	**15168**	13781	8	1379	**15168**	13781	8	1379	**15168**
3A	395	8	40	**443**	372	8	38	**418**	321	8	33	**362**	204	8	21	**233**
3B	589	8	60	**657**	553	8	56	**617**	472	8	48	**528**	244	8	25	**277**
4A	2965	1190	416	**4571**	2372	1055	343	**3770**	2050	984	303	**3337**	1524	873	240	**2637**
4B(1)	2380	1198	358	**3936**	1955	1063	302	**3320**	1723	992	272	**2987**	1338	881	222	**2441**
4B(2)	4000	1198	520	**5718**	3580	1063	464	**5107**	3348	992	434	**4774**	2963	881	384	**4228**
4C	4751	2541	729	**8021**	3402	1862	526	**5790**	2686	1508	419	**4613**	1546	956	250	**2752**
4D(1)	1807	2549	436	**4792**	1322	1870	319	**3511**	1056	1516	257	**2829**	617	964	158	**1739**
4D(2)	3432	2549	598	**6579**	2047	1870	392	**4309**	2681	1516	420	**4617**	2243	964	321	**3528**
5A	3890	2730	662	**7282**	3099	2267	537	**5903**	2674	2026	470	**5170**	1987	1650	364	**4001**
5B(1)	3380	2738	612	**6730**	2739	2275	501	**5515**	2391	2034	443	**4868**	1825	1658	348	**3831**
5B(2)	5005	2738	774	**8517**	4364	2275	664	**7303**	4016	2034	605	**6655**	3450	1658	511	**5619**
5C	8379	8524	1690	**18593**	6038	6208	1225	**13471**	4805	5002	981	**10788**	2859	3121	598	**6578**
5D(1)	5832	8531	1324	**15687**	4239	6216	1046	**11501**	3395	5010	841	**9246**	2056	3129	519	**5704**
5D(2)	7457	8531	1599	**17587**	5864	6216	1208	**13288**	5020	5010	1003	**11033**	3681	3129	681	**7491**
6	6460	0	646	**7106**	4602	0	460	**5062**	3624	0	362	**3986**	2076	0	208	**2284**
7A(1)	1801	1262	306	**3369**	1341	923	226	**2490**	1088	746	183	**2017**	670	470	114	**1254**
7A(2)	3426	1270	470	**5166**	2966	923	389	**4278**	2713	746	346	**3805**	2295	470	277	**3042**

Source: Arthur D. Little, Inc.

Table 4-9. Areas and Volumes of Contamination at Sites 15, 16, 17, 19, 31, 32-II According to Cleanup Level and Risk Scenarios

			Residential 1 x 10-6		Light Industrial 1 x 10-6		Light Industrial 1 x 10-5		Military 1 x 10-6	
Site	Risk (a)	HQ (a)	Area (sq ft)	Volume (cu yd)	Area (sq ft)	Volume (cu yd)	Area (sq ft)	Volume (cu yd)	Area (sq ft)	Volume (cu yd)
15	4E-04	200	88000	13333	66750	5000	66750	5000	0	0
16	9E-07	7	1800	417	3600	517	1800	167	900	17
17	2E-05	10	439	8	244	5	244	5	244	5
19	2E-02	300	26250	7772	26250	7772	11250	4531	11250	4531
31	1E-03	0.02	3550	362	3550	362	3550	362	1420	33
32-II	2E-05	2	17000	315	25000	463	25000	463	25000	463
Total			137039	22207	125394	14119	108594	10528	38814	5049
Total *			**137000**	**22500**	**125000**	**14100**	**109000**	**10600**	**38800**	**22500**

(a) Future Residential Risks and Hazards (See Table 1-8)

* Rounded to three significant figures

Note: Areas and volumes include uncertainty factor of 1.25

Source: Arthur D. Little, Inc.

Table 4-10: Comparison of Costs for Different Cleanup Levels at Sites 15, 16, 17, 19, 31, and 32-II by Various Risk Scenarios

Alter-native	Residential, 1 x 10-6				Light Industrial, 1 x 10-6				Light Industrial, 1 x 10-5				Military, 1 x 10-6			
	Capital ($000)	O&M ($000)	Design/ Planning ($000)	Total ($000)	Capital ($000)	O&M ($000)	Design/ Planning ($000)	Total ($000)	Capital ($000)	O&M ($000)	Design/ Planning ($000)	Total ($000)	Capital ($000)	O&M ($000)	Design/ Planning ($000)	Total ($000)
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2A	1094	8	110	1212	1094	8	110	1212	1094	8	110	1212	1094	8	110	1212
2B	6563	8	657	7228	6563	8	657	7228	6563	8	657	7228	6563	8	657	7228
2C	13781	8	1379	15168	13781	8	1379	15168	13781	8	1379	15168	13781	8	1379	15168
3A	266	8	27	301	256	8	26	290	243	8	25	276	192	8	20	220
3B	364	8	37	409	346	8	35	389	321	8	33	362	223	8	23	254
4A	2275	1042	292	3609	1778	927	271	2976	1560	878	244	2682	1202	800	200	2202
4B(1)	1875	1050	455	3380	1523	935	246	2704	1368	886	225	2479	1109	808	192	2109
4B(2)	3500	1050	429	4979	3148	935	408	4491	2993	886	388	4267	2734	808	354	3896
4C	3235	1798	303	5336	2099	1225	332	3656	1605	977	258	2840	814	588	140	1542
4D(1)	1235	1806	467	3508	829	1233	206	2268	650	985	164	1799	354	596	95	1045
4D(2)	2860	1806	479	5145	2454	1233	369	4056	2275	985	326	3586	1979	596	258	2833
5A	2984	2224	649	5857	2320	1833	415	4568	2029	1664	369	4062	1558	1399	296	3253
5B(1)	2637	2232	801	5670	2099	1841	394	4334	1863	1672	354	3889	1477	1407	288	3172
5B(2)	4262	2232	628	7122	3724	1841	557	6122	3488	1672	516	5676	3102	1407	451	4960
5C	5778	5991	1166	12935	3806	4037	784	8627	2950	3193	614	6757	1591	1866	346	3803
5D(1)	4048	5999	1005	11052	2707	4045	675	7427	2123	3201	532	5856	1192	1874	307	3373
5D(2)	5673	5999	1167	12839	4332	4045	838	9215	3748	3201	695	7644	2817	1874	469	5160
6	4387	0	439	4826	2832	0	283	3115	2151	0	215	2366	1073	0	107	1180
7A(1)	1257	891	215	2363	867	604	147	1618	702	480	118	1300	420	286	71	777
7A(2)	2882	891	89	3862	2492	604	310	3406	2327	480	281	3088	2045	286	233	2564

Source: Arthur D. Little, Inc.

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Appendix A: Environmental Fate and Transport Properties

Appendix A

Environmental Fate and Transport Properties

Potential human and environmental exposure to each of the contaminants of concern is influenced by physical/chemical properties and the environmental fate and transport properties of each contaminant. Summaries of the important physical/chemical and environmental fate parameters for the organic and inorganic contaminants of concern at at UMDA are presented in Tables A-1 and A-2 respectively. Fate and transport profiles for each of the contaminants of concern are presented in Appendix C of the RA.

Several of the parameters listed in Tables A-1 and A-2 are used to calculate estimated values for other parameters used in the exposure assessment of the RA. For example, molecular weight and the octanol-water partition coefficient (K_{ow}) were used to calculate the chemical-specific dermal permeability constant (K_p); K_{ow}s were used to calculate plant and animal uptake factors; and Henry's Law constants were used to estimate transfer efficiencies. Other parameters listed in Tables A-1 and A-2 (e.g., solubility, vapor pressure, diffusion coefficient, organic carbon partition coefficient, and physical state) were not used for risk and hazard calculations, but were useful in predicting potential relevant future exposure pathways and helping to link sources with currently contaminated media.

The source of this summary is Section 4.0 of the RA as supplemented by Appendix C of the RA.

Table A-1: Important Physical and Chemical Pro Contaminants of Concern

	CAS REG. NO.	CHEMICAL FORMULA	USATHAMA ABBR.	MOLECULAR WEIGHT (amu)	COLOR	FREEZING/ MELTING PT. (C)	BOILING POINT (C)	PHYSICAL STATE (at 20 C)	SOLID/ LIQUID DENSITY at 20 C (g/cm3)	FL PC (
VOA										
Benzene	71–43–2	C6H6	C6H6	78.11	Colorless to light yellow(b1)	5.5(j1)	80.1(j1)	liquid(k1)	0.8765(o1)	–11
Tetrachloroethylene	127–18–4	C2Cl4	TCLEE	165.83	Colorless(k1)	–22.4(k1)	121.2(k1)	liquid(k1)	1.625(k1)	
1,1,1–Trichloroethane	71–55–6	CH3CCL3	111TCE	133.42	Colorless(k1)	–33(w3)	74(w3)	liquid(k1)	1.325(w3)	
Trichloroethylene	79–01–6	C2HCl3	TRCLE	131.39	Colorless(g2)	–87.1(d4)	87.2(v3)	liquid(k1)	1.462(v3)	32.
Xylenes										
o–Xylene	95–47–6	C8H10	12DMB	106.16	Colorless(k1)	–25.2(w3)	144.4(w3)	liquid(k1)	0.8802(w3) at 25 C	31
m–Xylene	108–38–3	C8H10	13DMB	106.16	Colorless(k1)	–47.9(w3)	139.1(w3)	liquid(k1)	0.86417(w3) at 25 C	29
p–Xylene	106–42–3	C8H10	14DMB	106.16	Colorless(k1)	13.3(w3)	138.7(w3)	liquid(k1)	0.86105(w3) at 25 C	27
SVOA										
2–Methylnaphthalene	91–57–6	C11H10	2MNAP	142.21	•	34.58(a1)	241.1(a1)	solid(b1)	1.0058(c1)	97
Anthracene	120–12–7	C14H10	ANTRC	178.23	Colorless crystals, violet fluorescence(a1)	216(r1)	339.9(a1)	solid(a1)	1.134@	12.
Benzo(A)anthracene	56–55–3	C18H12	BAANTR	228.29	Yellow–blue(u1)	162(u1)	400(a1)	solid(w1)	1.274(w1)	
Benzo(B)fluoranthene	205–99–2	C20H12	BBFANT	252.3	Colorless(x1)	168.3(x1)	•	solid(u1)	1.174@	
Benzo(K)fluoranthene	207–08–9	C20H12	BKFANT	252.3	Pale yellow(x1)	215.7(x1)	480(x1)	solid(w1)	1.174@	
Bis(2–ethylhexyl)phthalate	117–81–7	C24H38O4	B2EHP	390.62	Colorless(b2)	–50(c2)	385(b1)	liquid(d2)	0.9861(d2)	21
Chrysene	218–01–9	C18H12	CHRY	228.3	Colorless w/red and blue fluorescence(i2)	255–256(i2)	448(i2)	rhombic plates(i2)	1.274(i2)	
Di–n–butyl phthalate	84–74–2	C16H22O4	DNBP	278.35	Colorless(b1)	–35(b1)	340(c1)	oily liquid(b1)	1.047(c1)	17
Dibenzofuran	132–64–9	C12H8O	DBFU	168.19	White(o3)	86–87(u1)	287(u1)	solid(o2)	1.30@	
Fluoranthene	206–44–0	C16H10	FANT	202.26	Colorless(a1)	111(q2)	367(a1)	solid(a1)	1.165@	
N–nitrosodiphenylamine	86–30–6	C12H10N2O	NNDPA	198.24	Yellow to green(k1)(d2)	66.5(r2)	268.17(s2)	crystals(k1)	1.23(r2)	61
Naphthalene	91–20–3	C10H8	NAP	128.19	White(b1)	80.55(q2)	218(c1)	solid(b1)	1.145(c1)	80
Phenanthrene	58–01–8	C14H10	PHANTR	178.23	Colorless(b1)	101(t2)	339(a1)	solid(a1)	1.134@	17
Pyrene	129–00–00	C16H10	PYR	202.3	Pale yellow or slight blue(x1)	156(k2)	404(k2)	solid(w1)	1.271(w1)	
PESTICIDES/PCBs										
DDD	72–54–8	C14H10CL4	DDD	320.05	Colorless(k1)	109–110(w1)	193(w1)	crystals(k1)	1.813@	
DDE	75–55–9	C14H8Cl4	DDE	318.02	White(r2)	88.4(r2)	•	crystalline(r2)	1.492@	
DDT	50–29–3	C14H9Cl5	DDT	354.5	Colorless to slightly off–white(e3)	108.5(r2)	260(r2)	crystals or powder(e3)	1.596@	72 77
Polychlorinated Biphenols PCB 1260	11096–82–5	C12H5Cl5(12%) C12H4Cl6(38%) C12H3Cl7(41%) C12H2Cl8(8%)	PCB260	375.7	Colorless(k1)	•	340–375(i3)	liquid(k1)	1.873–1.888@	
Chlordane	57–74–9	C10H6Cl18	CLDAN	409.8	Brown(w2)	cis:107–108.8; trans:103–105(t2)	175 at 2mmHg(k1)	liquid(k2)	1.59–1.63 at 25 C(k2)	56
Dieldrin	60–57–1	C12H8Cl6O	DLDRN	380.93	Buff to light tan(j2)	175–176(j2)	••	solid(j2)	1.7@	
Endrin	72–20–8	C12H8Cl6O	ENDRN	380.90	White(w1)	235(s1)	•	solid(w1)	1.7(p2)	27
EXPLOSIVES										
1,3,5–Trinitrobenzene	99–35–4	C6H3N3O6	135TNB	213.12	Yellow(a1)	122(q3)	•	solid(a1)	1.63(r3)	
1,3–Dinitrobenzene	99–65–0	C6H4N2O4	13DNB	168.11	Yellowish(b1)	89.8(b1)	300–302 at 770 mm Hg(b1)	solid(b1)	1.575(k3)	
2,4,6–Trinitrotoluene	118–96–7	C7H5N3O6	246TNT	227.13	Colorless(b1)	80.75(b4)	240(b1) (explodes)	solid(b1)	1.65(b4)	
2,4–Dinitrotoluene	121–14–2	CH3C6H3(NO2)2	24DNT	182.15	Yellow(b1)	72(n3)	300(b1)	solid(b1)	1.521(n3)	20
2,6–Dinitrotoluene	606–20–2	CH3C6H3(NO2)2	26DNT	182.14	Yellow(m2)	66(n3)	285(m3)	solid(b1)	1.538(n3)	
HMX	2691–41–0	C4H8N8O8	HMX	296.2	Colorless(k4)	286(n3)	•	solid(n3)	1.90(n3)	
Nitrobenzene	98–95–3	C6H5NO2	NB	123.11	Yellow(b1)	5.6(t2)	210.8(c1)	liquid(c1)	1.20(b1) at 25 C	87.
RDX	121–82–4	C3H6N6O6	RDX	222.15	White(a1)	205(t3)	•	solid(a1)	1.83(n3)	
Tetryl	479–45–8	C7H5N5O8	Tetryl	287.17	Yellow(c1)	129.5(n3)	••	solid(c1)	1.73(n3)	18

Chemical Properties of the Organic
ern

	SOLID/ LIQUID DENSITY at 20 C (g/cm3)	FLASH POINT (C)	SOLUBILITY IN WATER (mg/L at 20 C)	VAPOR PRESSURE (mm Hg at 20 C)	HENRY'S LAW CONSTANT (atm-m3/ mole at 20 C)	OCTANOL-WATER PARTITION COEFFICIENT (Kow)	ORGANIC-CARBON PARTITION COEFFICIENT (Koc)(mL/g)	DIFFUSION COEFFICIENT IN WATER/AIR (cm2/s at 20 C)
	0.8765(o1)	-11 (k1)	1780 (b1)	76 (b1)	5.4E-03 (i1)	131.90 (m1)	65 (n1)	8.99E-06@/**
	1.625(k1)	**	150 (p1)	14 (p1)	2.27E-02 (i1)	1,360.38 (m1)	665 (q1)	7.59E-06@/**
	1.325(w3)	*	950(w3)	100(p1)	1.72E-02(h4)~	309(i4)	152(j4)	8.11E-06@/**
	1.462(v3)	32.2(f3)	1,100(u3)	58.7(v3)	8.92E-03(i1)	194.98(a2)	127(n1)	8.43E-06@/**
	0.8802(w3) at 25 C	31(w3)	0.3(p1)	7(p1)	5.19E-03(x3)~	1,313.26(m1)	129(g1)	7.19E-06@/**
	0.86417(w3) at 25 C	29(w3)	0.3(p1)	9(p1)	7.19E-03(y3)~	1,534.89(m1)	166(g1)	7.19E-06@/**
	0.86105(w3) at 25 C	27(w3)	0.3(p1)	9(p1)	7.60E-03(y3)~	1,412.54(m1)	260(z3)	7.19E-06@/**
	1.0058(c1)	97(d1)	24.6(e1);25.4(f1)§	*	*	7,244(i1)	8,511(g1);7,413(h1)	6.43E-06@/**
	1.134@	121(a1)	0.073(f1)§	1.95E-04(r1)	1.45E-03(s1)	28,183.83(r1)	18,621(g1); 25,704(t1)	5.66E-06@/**
	1.274(w1)	*	0.009-0.014(x1)	2.2E-08(w1)	1.0E-06(w1)	4.1E+05(s1)	2.0E+05(s1)	5.11E-06@/**
	1.174@	*	0.014(y1)	(E-11)-(E-06)(s1)	1.22E-05(s1)	1.1E+06(w1)	5.5E+05(s1)	4.78E-06@/**
	1.174@	*	5.5E-04(z1)§	5.0E-07(s1)	3.87E-05(s1)	6.91E+06(a2)	5.5E+05(s1)	4.78E-06@/**
	0.9861(d2)	215(e2)	0.3(f2)§	6.45E-06(f2)++	1.1E-05(f2)~	7.586E+04(g2)	100,000(h2)	3.32E-06@/**
	1.274(i2)	*	0.0015-0.0022(x1)	6.3E-09(y1)	1.05E-06(y1)	4.1E+05(y1)	2.0E+05(y1)	5.11E-06@/**
:)	1.047(c1)	171(o2)	0.013(s1)	1.0E-05(s1)++	2.0E-07(s1)	3.98E+05(s1)	1.698E+05(s1)	4.22E-06@/**
	1.30@	*	10(t3)§	0.0044(g3)++	9.73E-05(w1)	1.31E+04(w1)	4,600-6,350(n2)	6.12E-6@/**
	1.165@	*	0.26(f1)§	0.01(a1)	6.5E-06(s1)	213,796.21(a2)	9,157@	5.39E-06@/**
	1.23(r2)	61(d1)	113(n1)§	6.3E-04(n1)++	1.4E-06(n1)~	1,348.96(m1)	650(n1)	5.13E-06@/**
	1.145(c1)	80(a1)	31.7(s1)(w1)	0.0492(s1)	4.6E-04(s1)	2,344(r1)	933.25(s1)	6.98E-06@/**
	1.134@	171(u2)	1.29(f1)§	6.8E-04(r1)	2.26E-04(s1)	28,840.32(r1)	5,248(g1);22,909(t1); 38,905(v2)	5.85E-06@/**
	1.271(w1)	*	0.125-0.165(x1)	2.5E-06(s1)++	5.1E-06(s1)	8.0E+04(s1)	3.8E+04(s1)	5.61E-06@/**
	1.813@	**	0.16 at 24 C(b1)	(1.3-2.5)E-09 at 30 C(t2)	3.1E-05(t2)~	363,078(c3)	240,000(c3)	4.49E-06@/**
·2)	1.492@	*	0.040(b1)	(6.2-8.6)E-06(d3)	1.9E-04(d3)~	489,778(d3)	257,000(d3)	4.55E-06@/**
	1.599@	72.2-77.2(f3)	0.0031-0.0034(b1)§	1.5E-07(e3)	5.13E-04(b3)	2.29E+06(h3)	302,000(c3)	4.32E-06@/**
	1.873-1.888@	*	0.0027(t2)	4E-05(t2)++	3.4E-04(j3)	1.2E+06-2.0E+09(n1)~	E+05-E+09(q1)	4.46E-06@/**
	1.59-1.63 at 25 C(k2)	56(a4)	0.056(x2); 1.850(y2)§	1.0E-05(z2)	4.8E-05(a3)~	346,736.85(b3)	3,090-43,652#	3.13E-06@/**
	1.7@	**	0.186(j2)	3.1E-06(k2)	2.0E-07(l2)	2.51E+04	1.1E+04@	4.33E-06@/**
	1.7(p2)	27(w1)	0.25(s1)§	2.7E-07(s1)++	4.0E-07(s1)	2.18E+05(s1)	1,698(s1)	4.33E-06@/**
	1.63(r3)	*	385(r3)§	3.03E-06(s3)++	2.21E-09(n3)~	15.14(n3)	19.95(p3)	7.2E-06 at 25 C(g4)/**
	1.575(k3)	*	533(l3)§	1.31E-04(m3)++	5.44E-08(n3)~	30.9(n3)	36.31(p3)	7.94E-06 at 25 C(g4)/**
	1.65(b4)	*	123(c4)	8.02E-06(f4)	1.1E-08(n3)~	100(n3)	524.8(n3)	6.71E-06(n3)/**
	1.521(n3)	207(w1)	280(n3)§	5.1E-03(s1)	1.86E-07(n3)~	95.50(n3)	251.20(n3); 44.67(s1)	7.31E-06(n3)/**
	1.538(n3)	*	180(s1)	0.018(s1)	4.86E-07(n3)~	77.62(n3)	77.62(n3);48.98(s1)	7.31E-06(n3)/**
	1.90(n3)	*	5.0(v1)	3.33E-14(n3)++	2.60E-15(n3)~	32(n3)	3.47(n3)	6.02E-06(n3)/**
	1.20(b1) at 25 C	87.7(o2)	1,900(b1)	0.15(b1)	1.53E-05(t2)~	70.8(t2)	36.31(s1)	7.72E-06@/**
	1.93(n3)	*	60(t3)§	4.03E-09(s3)(r3)++	1.96E-11(n3)~	7.41(n3)	100(e4)	7.15E-06(n3)/**
	1.73(n3)	187(c1)	80(n3)§	5.69E-09(n3)++	2.69E-11(n3)~	44.67(n3)	48.98(n3)	5.99E-06(n3)/**

References for Table A-1

a1=Sax and Lewis, 1989	a2=Leo et al., 1971	a3=Suntio et al., 1988	a4=OHM-TADS, 1988
b1=Verschueren, 1983	b2=CHRIS, 1978	b3=USEPA, 1986	b4=Linder, 1980
c1=Weast et al., 1985	c2=Patty, 1963	c3=Kadeg et al., 1986	c4=Spanggord et al., 1980a
d1=Aldrich Chemical Co., 1988	d2=IARC, 1982	d3=Arthur D. Little, Inc., 1987	d4=McNeil, 1979
e1=Eganhouse and Calder, 1976	e2=NFPA, 1978	e3=Clayton and Clayton, 1981	e4=Rosenblatt, 1986
f1=Mackay and Shiu, 1977	f2=Howard, 1989	f3=Weiss, 1986	f4=Pella, 1977
g1=Abdul et al., 1987	g2=HSDB, 1987	g3=Chao et al., 1983	g4=Lyman et al., 1982
h1=Hodson and Williams, 1988	h2=Neely and Blau, 1985	h3=Chiou et al., 1982	h4=Gossett, 1987
i1=Yoshida et al., 1983	i2=CRC, 1987	i3=Sittig, 1981	i4=Hansch and Leo, 1985
j1=Weast, 1977	j2=Worthing and Walker, 1983	j3=Burkhard et al., 1985	j4=Mabey et al., 1981
k1=Hawley, 1981	k2=Windholz, 1983	k3=Weast, 1979	k4=USEPA, 1988
l1=Mackay and Shiu, 1981	l2=Thomas, 1982	l3=Leiga and Sarmousakis, 1966	
m1=Leo, 1983	m2=USPHS, 1989	m3=Maksimov, 1963	
n1=Arthur D. Little, Inc., 1985	n2=Karickhoff, 1985	n3=Burrows et al., 1989	@=Dames & Moore calculation as per Section C.1.2
o1=Weast, 1984	o2=Sax and Lewis, 1987	o3=Sax, 1979	
p1=Mackison et al., 1981	p2=USEPA, 1980	p3=Lyman and Loreti, 1987	*=Value was not found during profile preparation
q1=Means et al., 1982	q2=Cleland and Kingsbury, 1977	q3=Clark and Hartman, 1941	
r1=Radding et al., 1976	r2=TDB, 1984	r3=Urbanski, 1985	**=Not relevant at normal environmental conditions
s1=Mabey et al., 1982	s2=USEPA, 1987	s3=Cundall et al., 1981	
t1=Karickhoff et al., 1979	t2=Callahan et al., 1979	t3=Banerjee et al., 1980	§=Solubility in Water (mg/L at 25 C)
u1=Weast et al., 1988	u2=NFPA, 1984	u3=Pearson and McConnell, 1975	++=Vapor Pressure (mm Hg at 25 C)
v1=Glover and Hoffsommer, 1973	v2=Socha and Carpenter, 1987	v3=Reid et al., 1977	~=Henry's Law Constant (atm-m3/mole at 25 C)
w1=HSDB, 1988	w2=Hartley and Kidd, 1983	w3=Grayson and Eckroth, 1978	
x1=IARC, 1983	x2=Sanborn et al., 1976	x3=Sanemasa et al., 1982	#=Estimated for pure chlordane by USPHS, 1988, using Equations 4-5 and 4-8 in Lyman et al., 1982
y1=USEPA, 1982	y2=Weil et al., 1974	y3=SRC, 1988	
z1=Walton, 1985	z2=Martin, 1972	z3=Vowles and Mantoura, 1987	

Full references are presented in Appendix C.3.

Table A-2: Important Physical and Chemical Properties of Contaminants of Concern (Continued)

	CAS REG. NO.	CHEMICAL FORMULA/ USATHAMA ABBR.	MOLECULAR WEIGHT (amu)	COLOR	PHYSICAL STATE (at 20 C)	VALENCE STATES	MELTING POINT (C)	BOILING POINT (C)	DENSITY at 20 C (g/cm3)	VAPOR PRESSURE (mm Hg at 20 C
INORGANICS										
Mercury §	7439–97–6(b)	Hg/HG(a)	200.59(b)	Silvery–white(b)	heavy, mobile, liquid metal; solid is malleable, may be cut by a knife(b)	+1,+2(g)	–38.87(b)	352.72(b)	13.534 at 25 C(b)++	2E–03 at 25 C(b)+
Nickel §	7440–02–0(b)	Ni/NI(a)	58.7(b)	Silvery(o)	solid(q)	+2; seldom +1,+3,+4(g)	1,455(q)	2,920(q)	8.90(q)	1 at 1,810 (c)++
Potassium	7440–09–7(c)	K/K(a)	39.0983(g)	Silvery–white metal(c)	solid(c)	+1(g)	63.2(g)	765.5(g)	0.862(c)	-
Selenium §	7782–49–2(b)	Se/SE(a)	78.96(b)	Metallic gray to black(b)	solid(b)	–2,+4,+6(d)	144; 217; 221(b)	685(b)	4.81(b)	1 at 356 C(b)++
Silver §	7440–22–4(b)	Ag/AG(a)	107.868(j)	Lustrous, white(j)	solid(r)	+1,+2(o)	961.93(j)	2,212 at 760mm Hg (j)	10.50(j)	liquid=100 at 1,865 C(j)++
Sodium	7440–23–5(c)	Na/NA(a)	22.9898(c)	Light–silvery white metal(o)	soft solid(o)	+1(o)	97.82(o)	881.4(o)	0.971(c)	1.2 at 400 C(c)++
Thallium §	7440–28–0(b)	Tl/TL(a)	204.38(b)	Bluish–white(b)	solid(b)	+1,+3(g)	303.5(b)	1,457 +/–10(b)	11.85(b)	1 at 825 C(c)++
Vanadium §	7440–62–2(r)	V/V(a)	50.942(r)	Silver–gray(r)	solid(r)	+2,+3,+4, +5(o)	1,890+/–10; 1,917(r,o)	3,880(r)	6.11 at 18.7 C(o)++	-
Zinc §	7440–66–6(b)	Zn/ZN(a)	65.38(b)	Bluish–white, lustrous metal(o)	solid(b)	+2(o)	419.5(o)	908(o)	7.14 at 25 C(b)++	1 at 487 C(b)++
ANIONS										
Cyanide § (see ref. notes)	57–12–5(l)	CN/CYN(a)	26.02(CN)(l)	Colorless (HCN)(n)	liquid (HCN)(n)	–1(n)	–13.2 (HCN)(n)	25.7 (HCN)(n)	0.6884 (HCN)(b)	620(HCN)(w)++
Nitrates	7697–37–2 (HNO3)(g)	NO3/NO3(a)	62.00(NO3)(d)	Bluish (NO3)(d)	gas (NO3)(d)	–1(NO3)(c)	–42 (HNO3)(d)	83 (HNO3)(d)	1.5027 at 25 C (HNO3)(d)++	-

...cal Properties of the Inorganic ...(Continued)

...SITY ...20 C ...cm3)	VAPOR PRESSURE (mm Hg at 20 C)	SOLUBILITY IN WATER (mg/L at 20 C)	SOLVENTS	FLAMMABILITY
534 ...C(b)++	2E–03 at 25 C(b)++	5.6E–03 g/100cc(b)	0.24 +0.012 in benzene, 0.1 in isopropyl ether, 0.24 in cyclohexane, 0.13 in octane(p)	not flammable(g)
...(q)	1 at 1,810 (c)++	insoluble(q)	insoluble(q)	powders may ignite spontaneously in air(c)
2(c)	•	reacts violently with water(g)	liquid ammonia, ethylene–diamine, aniline(x); reacts violently with alcohols (n–propanol through n–octanol, benzyl alcohol, cyclohexanol)(c)	highly flammable; violent explosion hazard(c)
(b)	1 at 356 C(b)++	insoluble(b)	insoluble in alcohol, slightly soluble in ether(c)	•
...(j)	liquid=100 at ...,865 C(j)++	insoluble(o)	nitric acid, hot sulfuric acid and alkali cyanide solutions(e)	dust is flammable(c)
(c)	1.2 at 400 C(c)++	reacts violently with water(c)	reacts exothermally with halogenated hydrocarbon(c); dissolves in mercury(o)	highly flammable; explosion danger when wet(c)
(b)	1 at 825 C(c)++	insoluble(b)	nitric or sulphuric acid(b)	dust is flammable(c)
at ...)++	•	insoluble(o)	aqua regia, HNO3, H2SO4, and HF(d)	dust is flammable; can react violently(c)
at ...)++	1 at 487 C(b)++	insoluble(b)	acetic acid and alkali (b)	flammable; may ignite spontaneously in air when dry; explosive reaction with acids(c)
4 ...b)	620(HCN)(w)++	miscible (HCN)(n)	ethanol(HCN)(b)	flammable; possibly explosive(c)
25 C ...)++	•	soluble (HNO3)(d)	ether(NO3)(d)	flammable and/or explosive(NO3)(c)

Table A-2: Important Physical and Chemical Properties of Contaminants of Concern

	CAS REG. NO.	CHEMICAL FORMULA/ USATHAMA ABBR.	MOLECULAR WEIGHT (amu)	COLOR	PHYSICAL STATE (at 20 C)	VALENCE STATES	MELTING POINT (C)	BOILING POINT (C)	DENSITY at 20 C (g/cm3)	VAPOR PRESSURE (mm Hg at 20
INORGANICS										
Aluminum §	7429–90–5(b)	Al/AL(a)	26.98(b)	Tin-white, with bluish tint(b)	solid, metals(b)	+3(e)	660(b)	2,327(b); 2,450(c)	2.70(b)	1 at 1,284 C(c
Antimony §	7440–36–8(b)	Sb/SB(a)	121.75(b)	Silvery white(b)	solid(b)	0,–3,+3,+5(f) 4(e)	630.5(b)	1,750(b); 1,325(t); 1,635(o)	6.688(t)	1 at 886 C(x)
Arsenic §	7440–38–2(b)	As/AS(a)	74.92(b)	Silver gray(b)	solid(b)	+2,+3,+5(e); 0,–3(f)	817 (28 atm)(b)	613 (sublimes)(b)	5.727(b)	0(s); 1 at 372 (sublimes)(g)
Barium §	7440–39–3(b)	Ba/BA(a)	137.3(b)	Silver-white(b)	malleable metal(e)	+2(b)	710(o); 725(b)	1,600(o); 1,640(b)	3.51(b)	10 at 1,049 C(v
Beryllium §	7440–41–7(b)	Be/BE(a)	9.012(b)	Steel gray(b)	solid; hexagonal structure(b)	+2(e)	1,287 to 1,292(b)	2,970(b)	1.846(b)	1 at 1,520 C(b)
Cadmium §	7440–43–9(b)	Cd/CD(a)	112.41(b)	Silver-white(b)	solid(b)	+2(e)	321(b)	765(b)	8.65(b)	1 at 1,284 C(e)
Calcium	7440–70–2(g)	Ca/CA(a)	40.08(e)	Silver-white(e)	solid (crystalline metal)(e)	+2(e)	850(g)	1,440(g)	1.54(g)	10 at 983(c)+
Chromium §	7440–47–3(b)	Cr/CR(a)	51.996(b)	Steel gray(b)	solid(b)	+2,+3,+6(e)	1,857(b)	2,672(e)	7.20 at 28 C(b)	1 at 1,616 C(b)
Cobalt §	7440–48–4(b)	Co/CO(a)	58.93(b)	Silvery gray(b)	solid(b)	+2,+3(e); 1, 2, 3, rarely 4 and 5(g)	1,495(b)	2,870(b)	8.9(b)	1 at 1,910 C(b)
Copper §	7440–50–8(b)	Cu/CU(a)	63.546(b)	Reddish(b)	solid(b)	+1,+2(e)	1,083.4(b)	2,567(b)	8.92(b)	1 at 1,628 C(k; 10 at 1,870 C(b)
Iron	7439–89–6(g)	Fe/FE(a)	55.847(f)	Silver(f)	solid(e)	+2,+3(e); seldom +1, +4,+6(g)	1,535(f)	2,750(f)	7.86(f)	•
Lead §	7439–92–1(b)	Pb/PB(a)	207.2(b)	Bluish-gray(b)	solid(b)	+2,+4(g)	327.4(b)	1,770(g)	11.35(b)	1 at 980 C(b)+
Magnesium	7439–95–4(c)	Mg/MG(a)	24.31(c)	Silvery-white metal(c)	solid(c)	+2(g)	651(y)	1,100(c)	1.738(c)	1 at 621 C(c)+
Manganese §	7439–96–5(b)	Mn/MN(a)	54.94(o)	Silver(b)	solid(b)	+1,+2,+3, +4,+6,+7(g)	1,244(z)	1,962(z)	7.20(z)	1 at 1,292 C(u

cal Properties of the Inorganic

ENSITY at 20 C g/cm3)	VAPOR PRESSURE (mm Hg at 20 C)	SOLUBILITY IN WATER (mg/L at 20 C)	SOLVENTS	FLAMMABILITY
.70(b)	1 at 1,284 C(c)++	insoluble(d)	soluble in alkali, HCl,H2SO4(f)	flammable solid; spontaneous combustion(c)
.688(t)	1 at 886 C(x)++	insoluble(b)	hot conc. H2SO4, aqua regia(f)	moderate fire and explosion hazard as dust or vapor(c)
727(b)	0(s); 1 at 372 C (sublimes)(g)++	insoluble(f)	Soluble HNO3(f)	dust is flammable when exposed to flame or through reaction with oxidizers(c)
.51(b)	10 at 1,049 C(v)++	decomposes (temp. unspecified)(v)	alchohol(b)	dust is flammable or explosive(e)
346(b)	1 at 1,520 C(b)++	insoluble(i)	dilute acid and alkali(b)	forms explosive mixtures in air(h)
65(b)	1 at 1,284 C(e)++	insoluble(c)	acids, esp. nitric and ammonium nitrate solutions (f)	combustible; flammable; sometimes explosive(c)
54(g)	10 at 983(c)++	decomposes(f)	acids(e)	flammable; spontaneous combustion; moderately explosive(c,h)
28 C(b)	1 at 1,616 C(b)++	insoluble(b)	insoluble(b)	ignites and is potentially explosive(c)
9(b)	1 at 1,910 C(b)++	insoluble(b)	acids(b)	flammable; possibly explosive(c)
92(b)	1 at 1,628 C(k); 10 at 1,870 C(b)++	insoluble(b)	nitric acid and hot conc. sulfuric acid(e); HCl; NH4OH(f)	flammable(e); possibly explosive(c)
36(f)	•	insoluble(f)	acids(f)	powder is pyrophoric and potentially explosive(c)
35(b)	1 at 980 C(b)++	insoluble(b)	HNO3,hot conc. H2SO4(d)	dust is flammable; moderately explosive(c)
38(c)	1 at 621 C(c)++	reacts violently with water, moisture(c)	acids(e)	powder is flammable particularly in the presence of water; may explode or react violently(c)
0(z)	1 at 1,292 C(u)	decomposes(b)	dissolves in dilute mineral acid(e)	dust or powder is flammable(e)

References for Table A-2

a=IRDMIS (May 30, 1990)	i=USEPA (1980)	r=Grayson (1983)	*=Value was not found during profile preparation
b=USPHS (see §)	j=Weast (1988)	s=USEPA (1981)	**=Not relevant at normal environmental conditions
c=Sax and Lewis (1989)	k=Callahan et al. (1979)	t=Herbot et al. (1985)	++=Value found for temperature other than 20 C
d=Weast (1989)	l=Arthur D. Little, Inc. (1987)	u=Kirk-Othmer (1967)	
e=Hawley (1981)	m=HSDB (1991)	v=USEPA (1984)	
f=Weast (1982)	n=Clayton and Clayton (1981)	w=Verschueren (1983)	
g=Budavari (1989)	o=Windholz (1983)	x=HSDB (1989)	
h=National Fire Protection Association (1986)	p=Spencer and Voight (1968)	y=Rose et al. (1979)	
	q=Weast (1986)	z=Cotton and Wilkinson (1962)	

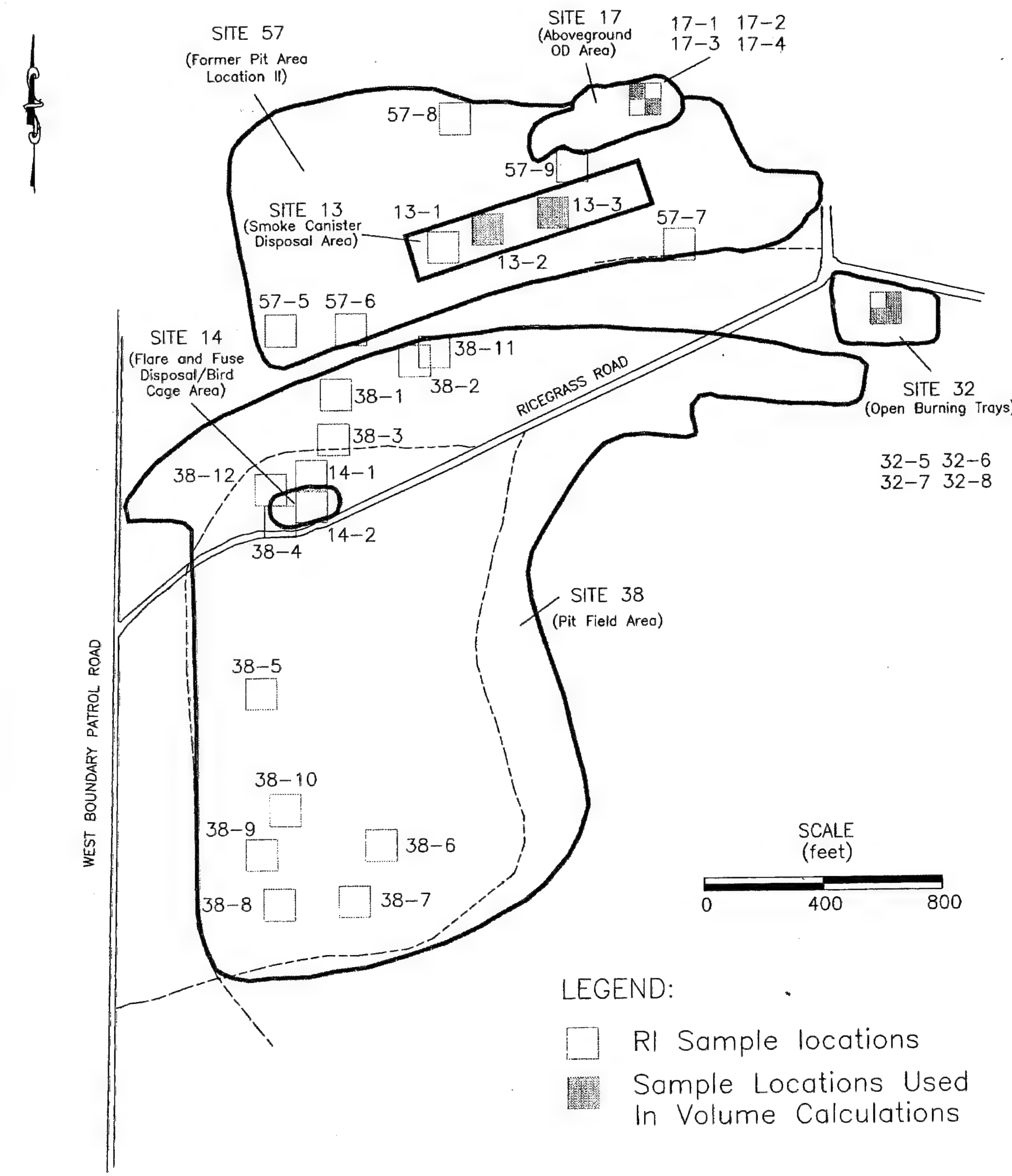
§ = USPHS toxilogical profiles are available for each of the following inorganics:

Aluminum October,1990	Cadmium November,1987	Lead February,1988	Silver December,1990
Antimony October,1990	Chromium October,1987	Manganese October,1990	Thallium October,1990
Arsenic November,1987	Cobalt October,1990	Mercury December,1989	Vanadium October,1990
Barium October,1990	Copper December,1990	Nickel October,1987	Zinc December,1989
Beryllium October,1987	Cyanide January,1988	Selenium December,1989	

Note re: cyanide:
Additional properties:
Odor Threshold in Air: 0.58 ppm (v/v)
Odor Threshold in Water: 0.17 ppm (w/v)
Henry's Law Constant: 1.22E-04 atm-m3/mole at 25 C(f1)++

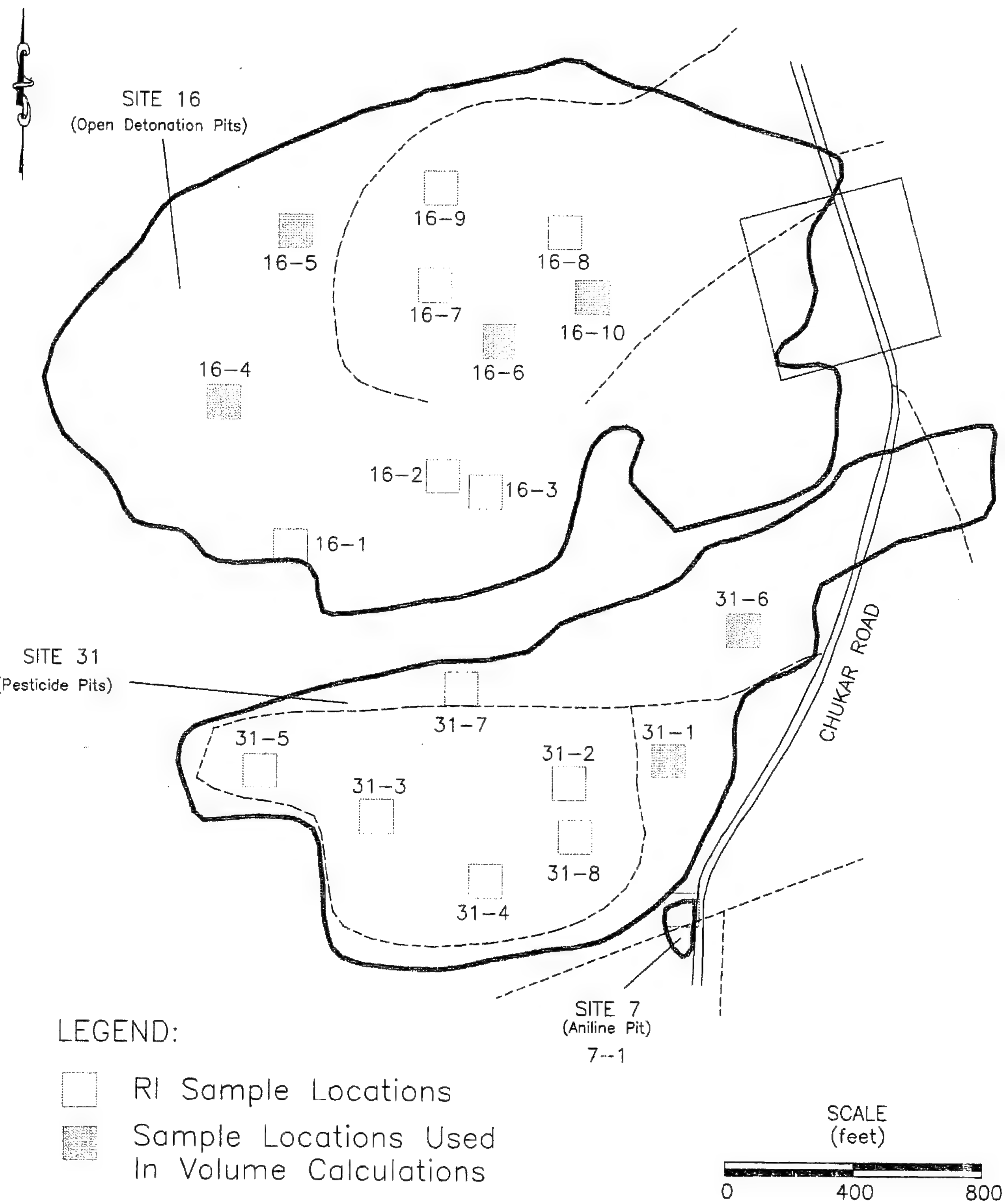
Full references are presented in Appendix C.3.

Appendix B: Area and Volume Calculation Worksheet and Maps



SOURCE: Reference 2
and Arthur D. Little, Inc.

Figure B-1. Soil Sample Locations at Sites 13, 17, and 32



SOURCE: Reference 2 and Arthur D. Little, Inc.

Figure B-2. Soil Sample Locations at Sites 16 AND 31

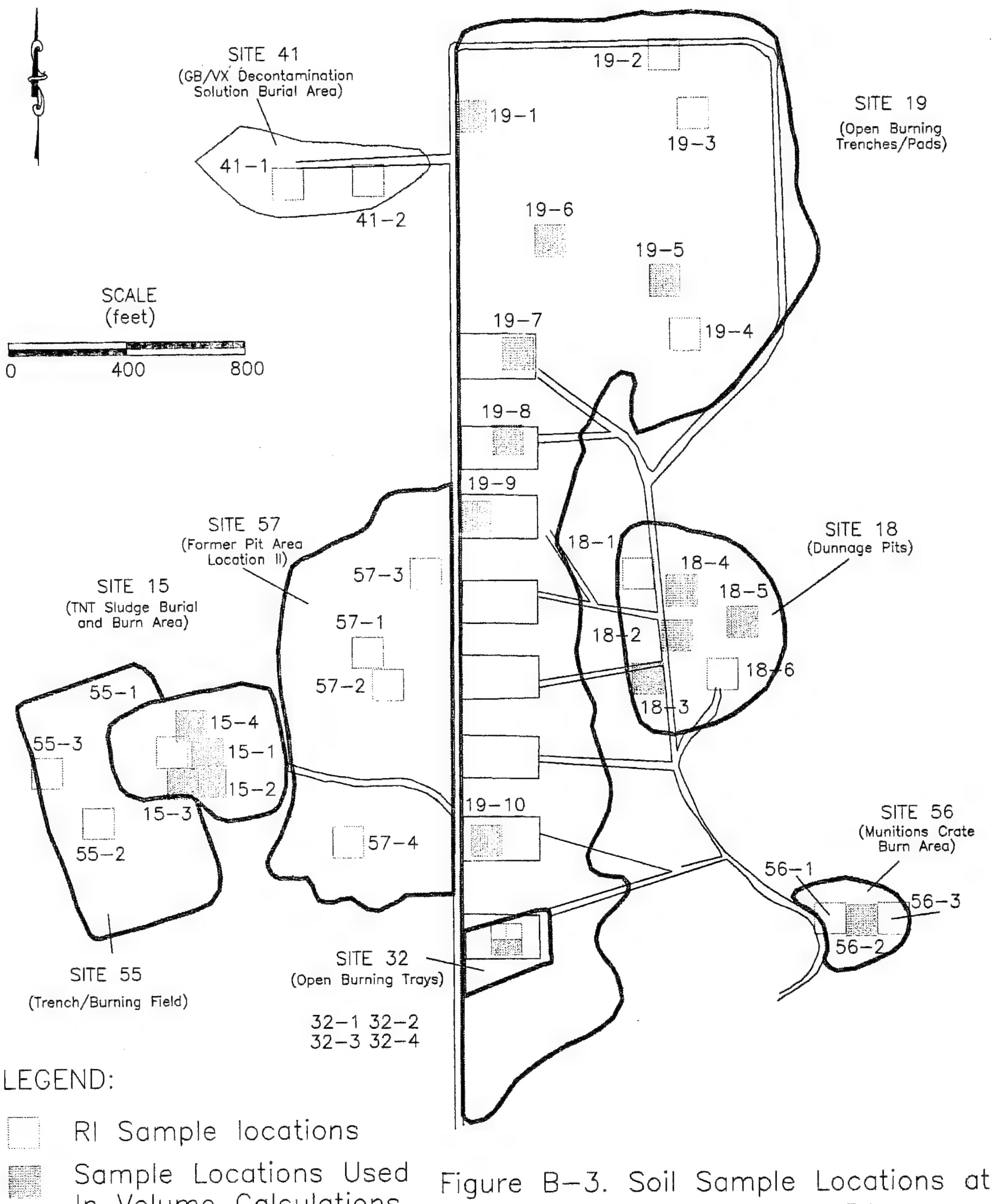
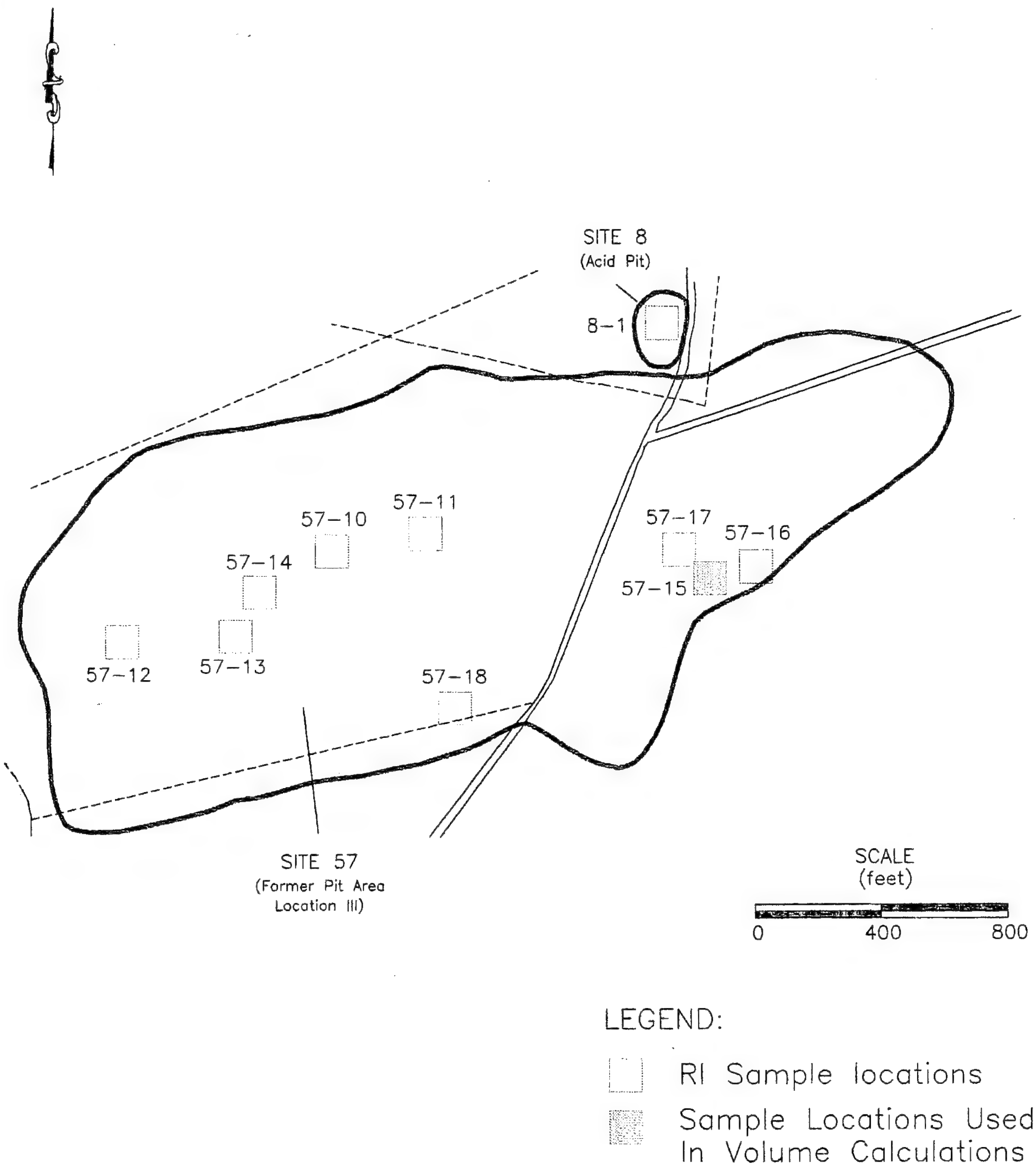


Figure B-3. Soil Sample Locations at Sites 15, 18, 19, 32, and 56

SOURCE: Reference 2
and Arthur D. Little, Inc.



SOURCE: Reference 2
and Arthur D. Little, Inc.

Figure B-4. Soil Sample Locations at Site 57

Table B-1. Contaminated Area and Volume Worksheet

	Residential 1.00E-06					Light Industrial 1.00E-06					Light Industrial 1.00E-05					Military 1.00E-06				
Site/ Location (a)	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)
13/A	180	35	6300	3	700	180	35	6300	3	700										
13/B	180	35	6300	3	700	180	35	6300	3	700	180	35	6300	3	700					
13 TOTALS			12600		1400			12600		1400			6300		700					
with 1.25 uncertainty factor			15750		1750			15750		1750			7875		875					
15/A	300	160	48000	2.5	4444															
15/B	140	160	22400	7.5	6222															
15/C						300	150	45000	1	1667	300	150	45000	1	1667					
15/D						140	60	8400	7.5	2333	140	60	8400	7.5	2333					
15 TOTALS			70400		10667			53400		4000			53400		4000					
w/1.25 uncertainty factor			88000		13333			66750		5000			66750		5000					
16/4 circ pits			720	2.5	67															
16/4 circ pits			720	10	267			720	10	267										
16/8 circ pits								1440	2.5	133			1440	2.5	133			720	0.5	13
16/4 circ pits								720	0.5	13										
16 TOTALS			1440		333			2880		413			1440		133			720		13
w/1.25 uncertainty factor			1800		417			3600		517			1800		167			900		17
17 TOTALS	13	27	351	0.5	7	13	15	195	0.5	4	13	15	195	0.5	4	13	15	195	0.5	4
w/1.25 uncertainty factor			439		8			244		5			244		5			243.75		5

Table B-1. Contaminated Area and Volume Worksheet (continued)

Site/ Location (s)	Residential 1.00E-06					Light Industrial 1.00E-06					Light Industrial 1.00E-05					Military 1.00E-06				
	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)
18/A	40	120	4800	5	889															
18/B	40	100	4000	10	1481	40	100	4000	10	1481	40	100	4000	10	1481	40	100	4000	10	1481
18/C	30	80	2400	7.5	667	30	80	2400	7.5	667	30	80	2400	7.5	667	30	80	2400	7.5	667
18/D	30	60	1800	7.5	500	30	60	1800	7.5	500	30	60	1800	7.5	500	30	60	1800	7.5	500
18/E	30	80	2400	7.5	667	30	80	2400	7.5	667	30	80	2400	7.5	667	30	80	2400	7.5	667
18/F	30	80	2400	10	889	30	80	2400	10	889	30	80	2400	10	889	30	80	2400	10	889
18 TOTALS			17800		5093			13000		4204			13000		4204			13000		4204
w/1.25 uncertainty factor			22250		6366			16250		5255			16250		5255			16250		5255
19/A	200	20	4000	10	1481	200	20	4000	10	1481										
19/B	200	20	4000	2.5	370	200	20	4000	2.5	370										
19/C	200	20	4000	5	741	200	20	4000	5	741										
19/D	150	15	2250	40	3333	150	15	2250	40	3333	150	15	2250	40	3333	150	15	2250	40	3333
19/E	150	15	2250	0.5	42	150	15	2250	0.5	42	150	15	2250	0.5	42	150	15	2250	0.5	42
19/F	150	15	2250	0.5	42	150	15	2250	0.5	42	150	15	2250	0.5	42	150	15	2250	0.5	42
19/G	150	15	2250	2.5	208	150	15	2250	2.5	208	150	15	2250	2.5	208	150	15	2250	2.5	208
19 TOTALS			21000		6218			21000		6218			9000		3625			9000		3625
w/1.25 uncertainty factor			26250		7772			26250		7772			11250		4531			11250		4531
31/2 pits			1420	5	263			1420	5	263			1420	5	263					
31/2 pits			1420	0.5	26			1420	0.5	26			1420	0.5	26			1420	0.5	26
31 TOTALS			2840		289			2840		289			2840		289			1420		26
w/1.25 uncertainty factor			3550		362			3550		362			3550		362			1775		33

Table B-1. Contaminated Area and Volume Worksheet (continued)

Site/	Residential 1.00E-06					Light Industrial 1.00E-06					Light Industrial 1.00E-05					Military 1.00E-06				
Location (a)	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)	Dimensions (ft)		Area (sq ft)	Depth (ft)	Volume (cu yd)
32-II/A	80	70	5600	0.5	104	80	70	5600	0.5	104	80	70	5600	0.5	104	80	70	5600	0.5	104
32-II/B	100	80	8000	0.5	148	100	80	8000	0.5	148	100	80	8000	0.5	148	100	80	8000	0.5	148
32-II/D						80	80	6400	0.5	119	80	80	6400	0.5	119	80	80	6400	0.5	119
32-II TOTALS			13600		252			20000		370			20000		370			20000		370
w/1.25 uncertainty factor			17000		315			25000		463			25000		463			25000		463
32-I/C TOTALS	190	130	24700	0.5	457	190	130	24700	0.5	457										
w/1.25 uncertainty factor			30875		572			30875		572										
56 TOTAL			5000	1.5	278															
w/1.25 uncertainty factor			6250		347															
57-III TOTAL	250	250	62500	0.5	1157	250	250	62500	0.5	1157	250	250	62500	0.5	1157					
w/1.25 uncertainty factor			78125		1447			78125		1447			78125		1447					

(a) Refer to following diagrams for key to locations

Source: Arthur D. Little, Inc.

Table B-2. Summary of Post-RI Soil Sampling and Analysis Results

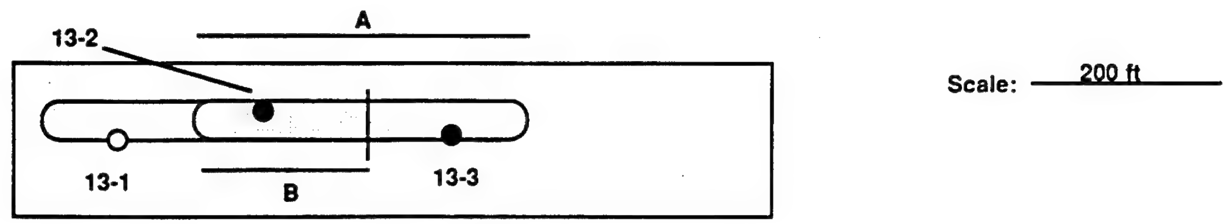
Sample No. (Site-Sample)	Depth (ft)	Residential 1.00E-06		Light Industrial 1.00E-06		Light Industrial 1.00E-05		Military 1.00E-06	
		Cont. (a)	Conc (ppm)	Cont. (a)	Conc (ppm)	Cont. (a)	Conc (ppm)	Cont. (a)	Conc (ppm)
15-5	0	RDX	35						
15-9	0	135 TNB	11.3	135 TNB	11.3	135 TNB	11.3	135 TNB	11.3
15-9	0	RDX	83	RDX	83				
15-9	0	246TNT	300	246TNT	300	246TNT	300	246TNT	300
15-9	0	Pb	1100	Pb	1100	Pb	1100	Pb	1100
15-10	0	RDX	7.02						
15-11	0	24DNT	6.2	24DNT	6.2	24DNT	6.2	24DNT	6.2
15-11	0	RDX	6.83						
15-11	0	26DNT	0.23	26DNT	0.23				
18-9	5	As	10.2	As	10.2	As	10.2	As	10.2
18-9	7.5	Pb	800	Pb	800	Pb	800	Pb	800
18-9	5	Pb	2600	Pb	2600	Pb	2600	Pb	2600
18-11	7.5	Pb	800	Pb	800	Pb	800	Pb	800
19-11	40	135TNB	1.18						
19-11	30	246TNT	12	246TNT	12	246TNT	12	246TNT	12

(a) Only those contaminants with concentrations exceeding the PRG (or action level for Pb) for the risk level are provided

Source: Data provided by USAEC

Appendix B – Diagrams to Support Table B-1

Site 13 - Contaminated soil volume estimates



For R-6 and LI-6:

13-2 to 3 feet
13-3 surface

Area/depth of contamination:

Boundary of contaminated area estimated to be: 1/2 distance from sample 13-2 to uncontaminated sample 13-1, eastern edge of mound, southern and northern edges of mound. 360 x 35 ft. Depth of 3 ft.

For LI-5:

13-2 to 3 feet

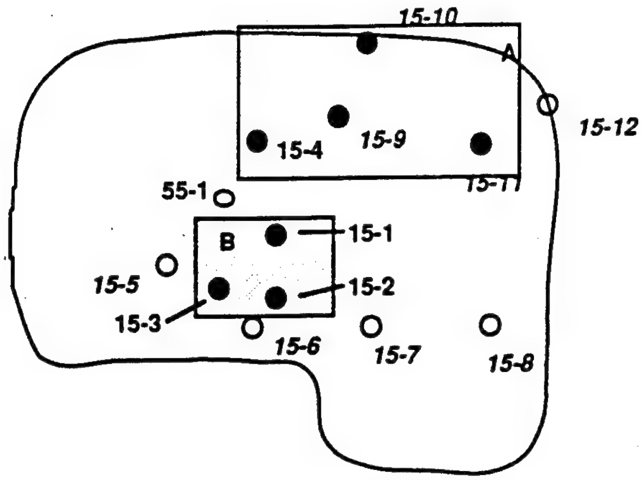
Area /depth of contamination:

Boundary of contaminated area estimated at: 1/2 distance from sample 13-2 to samples 13-1 and 13-3. 180 x 35 ft. Depth of 3 ft.

Site 15 - Contaminated Soil Volume Estimates

Revised estimates based on post-RI sampling and analyses (newer samples are italicized)

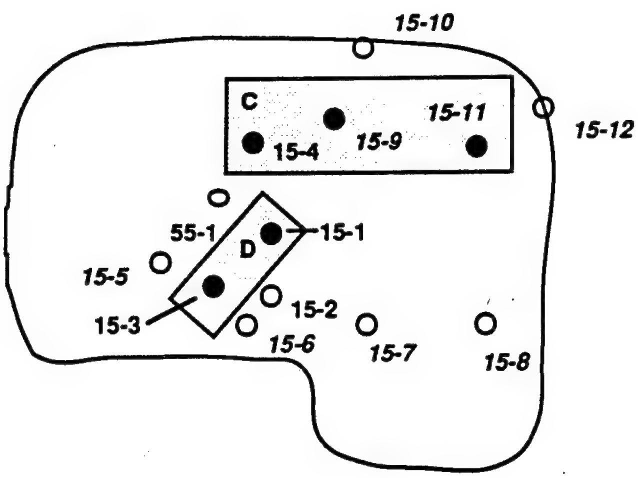
Scale: 200 ft



For R-6:

15-1 to 7.5 ft
15-2 to 1 ft
15-3 to 3 ft
15-4 to 2.5 ft
15-9 surface
15-10 surface
15-11 surface

Areas/depth of contamination:
A - Northern site edge, 1/2 distance to uncontaminated sample sites (15-12, 55-1). 300 x 160 ft. Depth of 2.5 ft.
B - 1/2 distance to uncontaminated sample sites (15-5, 55-1, 15-6, 15-7). 140 x 160 ft. Depth of 7.5 ft.



For LI-6 and LI-5:

15-1 to 7.5 ft
15-3 to 3 ft
15-4 to 1 ft
15-9 surface
15-11 surface

Areas/depth of contamination:
C - 1/2 distance to uncontaminated sample sites (55-1, 15-12, 15-10). 300 x 150 ft. Depth of 1 ft.

D - 1/2 distance to uncontaminated sample sites (15-5, 15-6, 15-2, 55-1). 140 x 60 ft. Depth of 7.5 ft.

Site 16 - Contaminated soil volume estimates

Contaminated soil volume estimates based on the presence of 40 pits and the results of sampling of 10 of the 40 pits. Each pit is approximately 15 ft in diameter (surface area of approximately 177 ft2)

Of 10 samples, R-6 level contamination in 2.
Therefore, assume that 20% of the 40 pits (total) are contaminated = 8 pits.
Using contamination profile of existing samples -
- **4 pits are contaminated to a depth of 2.5 ft.**
- **4 pits are contaminated to a depth of 10 ft.**

Of 10 samples, LI-6 level contamination in 4.
Therefore, assume that 40% of the 40 pits (total) are contaminated = 16 pits.
Using contamination profile of existing samples -
- **8 pits are contaminated to a depth of 2.5 ft.**
- **4 pits are contaminated to a depth of 10 ft.**
- **4 pits are contaminated to a depth of 0.5 ft.**

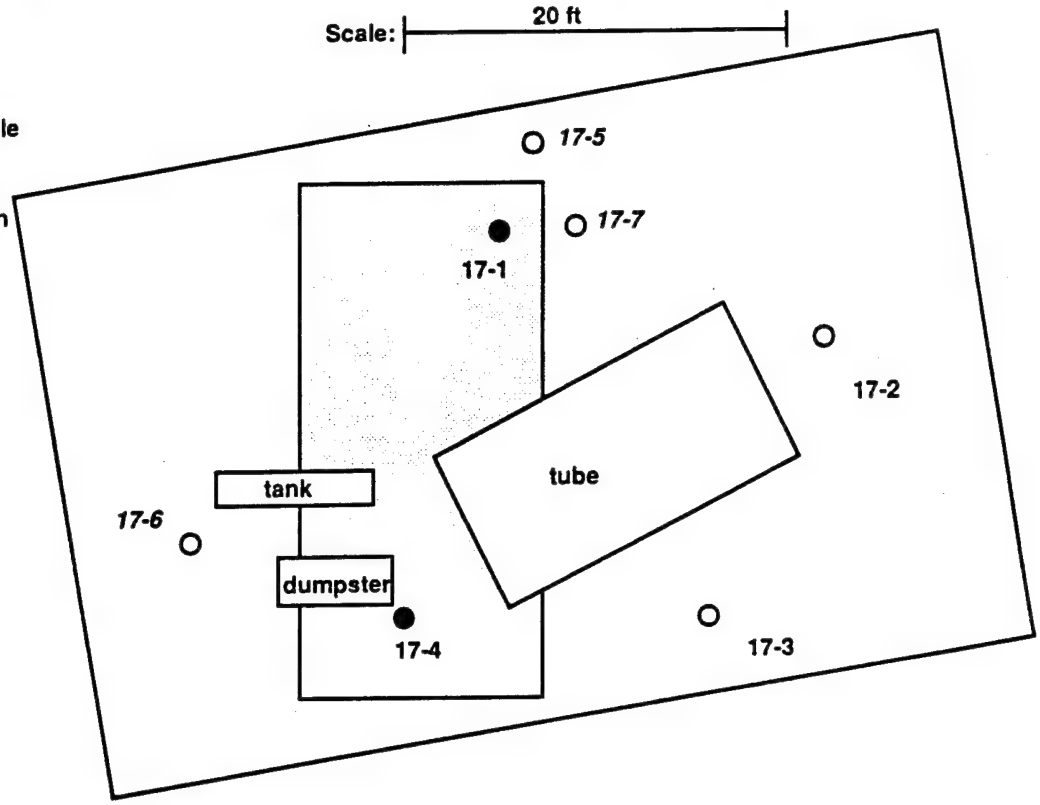
Of 10 samples, LI-5 level contamination in 2.
Therefore, assume that 20% of the 40 pits (total) are contaminated = 8 pits.
Using contamination profile of existing samples -
- **8 pits are contaminated to a depth of 2.5 ft.**

Of 10 samples, M level contamination in 1.
Therefore, assume that 10% of the 40 pits (total) are contaminated = 4 pits.
Using contamination profile of existing samples -
- **4 pits are contaminated to a depth of 0.5 ft.**

Site 17 - Contaminated soil volume estimates

Revised estimates based on post-RI sampling and analyses (newer samples are italicized)

Note - only sample locations and area considered for contamination are shown to scale



R-6: 17-1 at surface
17-4 at surface

Area/depth of contamination: 1/2 distance
to northern and southern edge of site, 1/2 distance to uncontaminated sample sites as shown. 13 x 27 ft. Depth of 0.5 ft.

LI-6, LI-5, M: 17-1 at surface

Area/depth of contamination:
13 x 15
Depth of 0.5 ft.

Site 18 - Contaminated Soil Volume Estimates

Revised estimates based on post-RI sampling and analyses (newer samples are italicized)

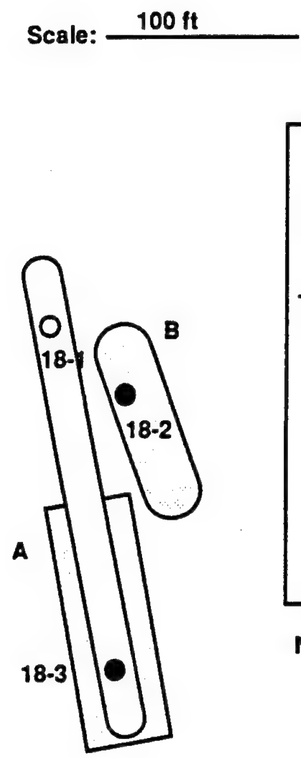
Note - only sample locations and area considered for contamination are shown to scale. Samples located according to state planar coordinates provided.

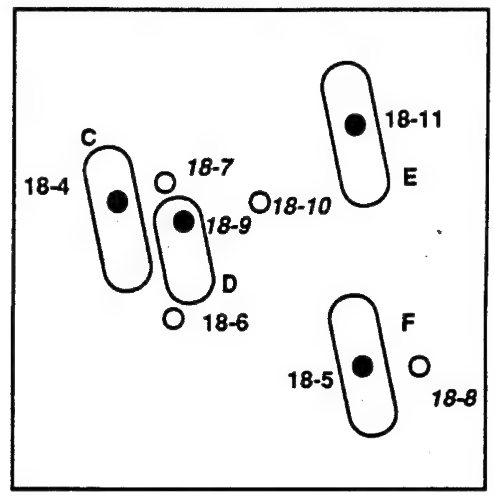
For R-6:

18-2 to 10 ft
18-3 to 5 ft
18-4 to 7.5 ft
18-5 to 10 ft
18-9 to 7.5 ft
18-11 to 7.5 ft

Areas of contamination:

A - 40 x 120 - 1/2 area of pit.
B - 40 x 100 - area of pit.
C - 30 x 80 - 1/2 area of pit.
D - 30 x 60 - area of pit between uncontaminated samples.
E - 30 x 80 - 1/2 area of pit.
F - 30 x 80 - 1/2 area of pit.





Note: 18-4 at north end of one pit
18-9 at north end of one pit
18-6 at south end of one pit
18-10 at north end of one pit
18-11 at north end of one pit
18-5 at middle of one pit
18-8 at middle of pit with 18-5

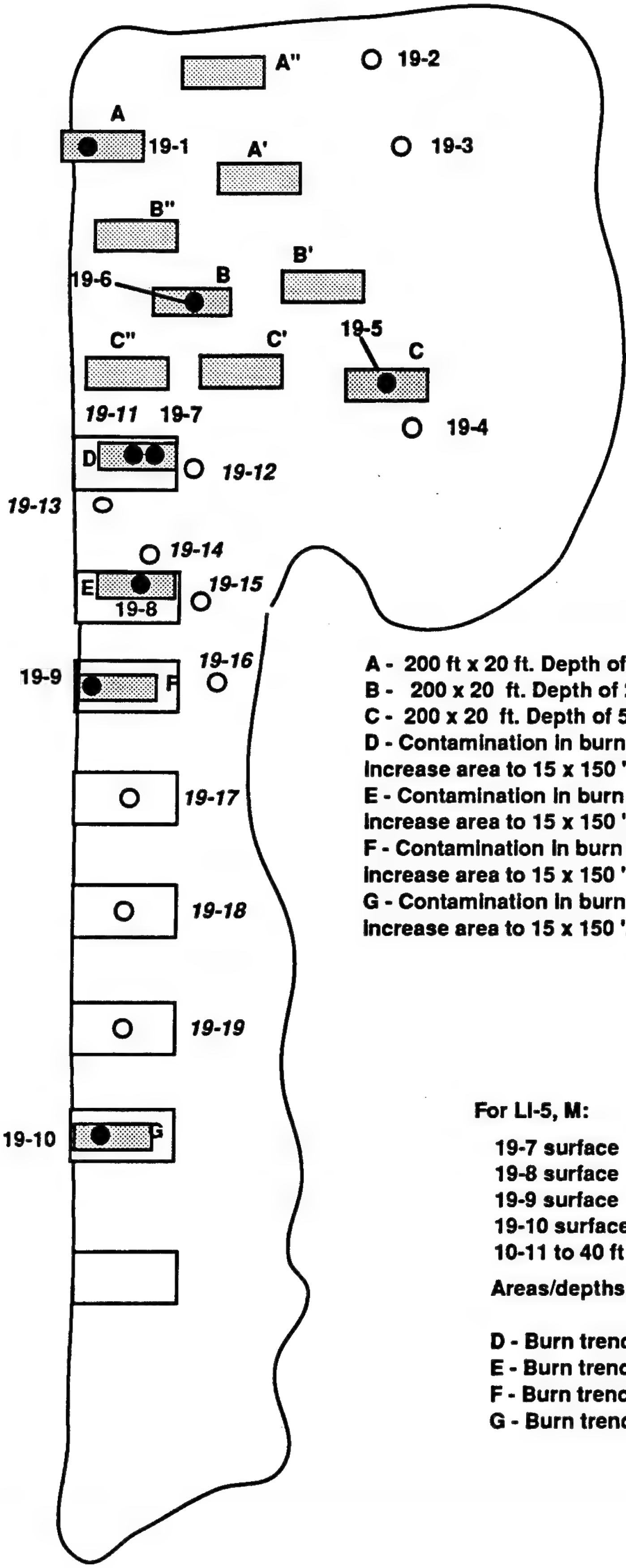
For LI-6, LI-5, M:

18-2 to 10 ft
18-4 to 7.5 ft
18-5 to 10 ft
18-9 to 7.5 ft
18-11 to 7.5 ft

B, C, D, E, F

Site 19 - Contaminated soil volume estimates

Revised estimates based on post-RI sampling and analyses (newer samples are italicized)



Scale: 400 ft

For R-6 and LI-6:

19-1 to 10 ft, 19-5 to 5 ft, 19-6 to 2.5 ft
19-7 surface, 19-8 surface, 19-9 surface
19-10 2.5 ft, 19-11 to 40 ft

Areas/depths of contamination:
Areas A, B, and C reflect contamination in an area in which burn pits had been identified in historical photographs. Assume that these pits were roughly the same dimension as the other, better defined pits (10 x 100) - because of evidence of significant amount of grading in the area, assume that each contaminated area is approximately 200 x 20 ft = 4000 sf. Because of the presence of additional historical pits, it is assumed that the frequency of contamination in this area is greater than indicated by available analyses. For the purposes of this estimation, assume that similar contamination to areas A, B, and C is triplicated in the northern burn field area. A', B', and C' have been located in areas adjacent to known contaminated areas but within the site boundaries and within the area bounded by known uncontaminated soil.

A - 200 ft x 20 ft. Depth of 10 ft.
B - 200 x 20 ft. Depth of 2.5 ft.
C - 200 x 20 ft. Depth of 5 ft.
D - Contamination in burn trench with dimensions of 10x100. Due to some grading, increase area to 15 x 150 '. Depth 40 ft
E - Contamination in burn trench with dimensions of 10x100. Due to some grading, increase area to 15 x 150 ' Depth of 0.5 ft.
F - Contamination in burn trench with dimensions of 10x100. Due to some grading, increase area to 15 x 150 ' Depth of 0.5 ft.
G - Contamination in burn trench with dimensions of 10x100. Due to some grading, increase area to 15 x 150 '.Depth of 2.5 ft.

For LI-5, M:

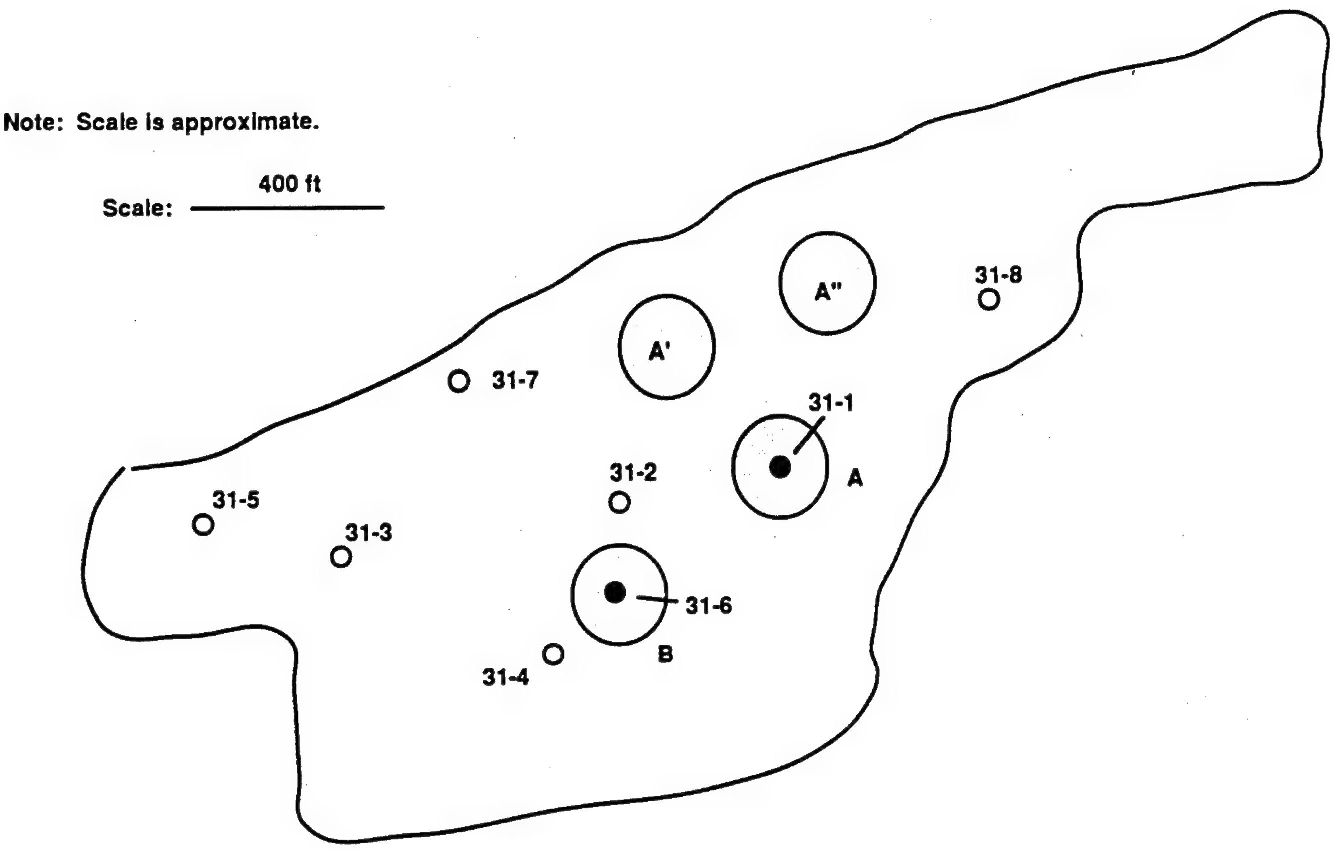
19-7 surface
19-8 surface
19-9 surface
19-10 surface
10-11 to 40 ft

Note: No samples were taken in burn trench south of trench in which sample 19-10 was taken

Areas/depths of contamination:

D - Burn trench, 15 x 150, Depth of 40 ft.
E - Burn trench, 15 x 150, Depth of 0.5 ft.
F - Burn trench, 15 x 150, Depth of 0.5 ft.
G - Burn trench, 15 x 150, Depth of 0.5 ft.

Site 31 - Contaminated Soil Volume Estimates



For RI-6, LI-6, and LI-5:

31-1 to 5 feet
31-6 at surface

For M

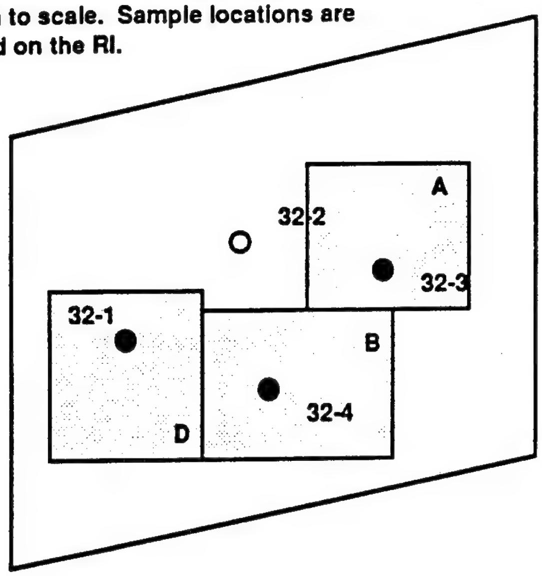
31-6 at surface

Assume contamination is limited to apparent disposal pits (diameter of 15 ft); however, due to grading over the years, it is likely that contamination may have spread. Contaminated areas estimated as circular with a diameter approximately equal to 2 times apparent pit size. Diameter = 30 feet. Area = 710 sf. 1 circular area contaminated to a depth of 5 feet; the other to a depth of 0.5 ft. Since not all pits were sampled, assume that contamination similar to A occurs at A' and A" (located in areas between uncontaminated samples.

Site 32 - Contaminated soil volume estimates

Scale: 100 ft

Note: Only site boundaries and estimated contaminated areas are drawn to scale. Sample locations are estimated based on the RI.

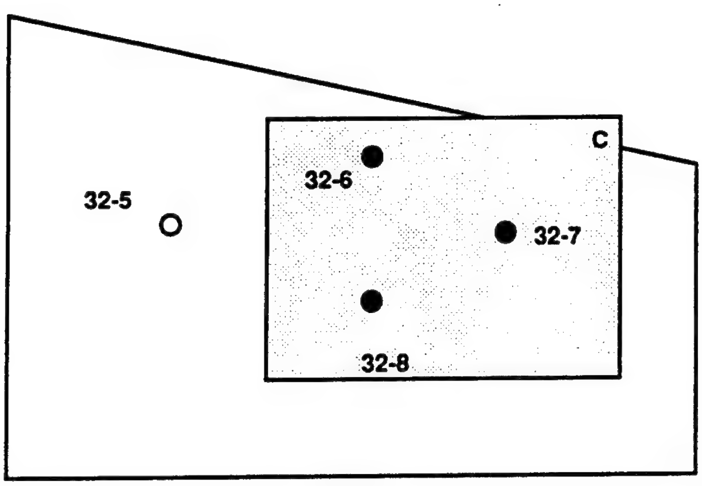


For R-6:

- 32-3 - surface
- 32-4 - surface
- 32-6 - surface
- 32-7 - surface
- 32-8 - surface

Area/depth/volume of contamination:

A - 1/2 distance from sample to northern and eastern edges of site, 1/2 distance to uncontaminated sample, 1/2 distance to contaminated sample 32-4: 80 x 70, 0.5 ft deep.
B - 1/2 distance from sample to southern and eastern edges of site, 1/2 distance to uncontaminated sample, 1/2 distance to contaminated sample 32-3: 100 x 80, 0.5 ft deep
C - 1/2 distance from contaminated samples to norther, eastern, and southern edges of site, 1/2 distance from contaminated samples to uncontaminated sample 32-5: 190 x 130, 0.5 ft deep



For LI-6:

- 32-1 - surface
- 32-3 - surface
- 32-4 - surface
- 32-6 - surface
- 32-7 - surface
- 32-8 - surface

Area and depth of contamination:

A, B, C - see above

D - 1/2 distance to uncontaminated sample 32-2, 1/2 distance to contaminated samples, 1/2 distance to western edge of site: 80 x 80, 0.5 ft deep

For LI -5:

- 32-1 - surface
- 32-3 - surface
- 32-4 - surface

Area and depth of contamination:

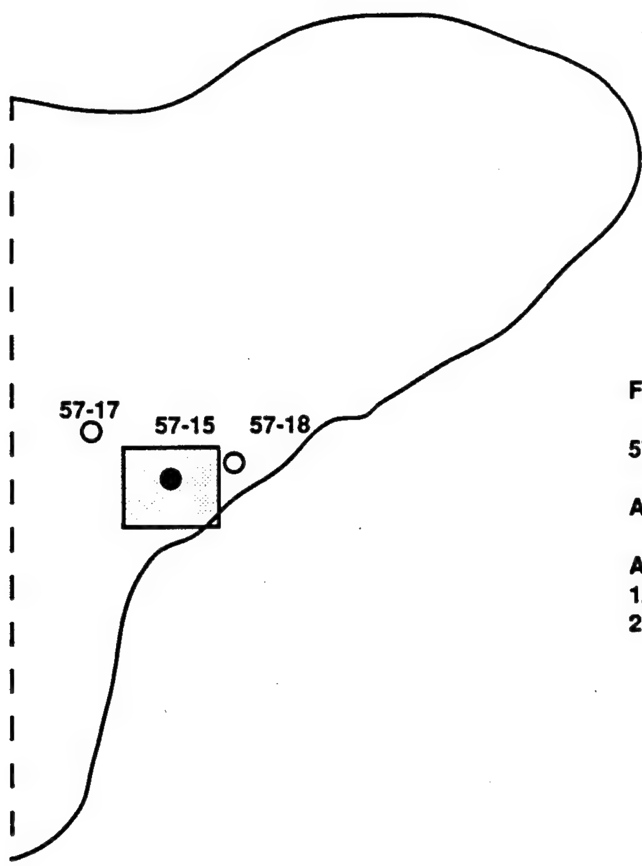
A, B, D - see above

Site 56 - Contaminated Soil Volume Estimates

For RI-6 only:

Sample pits located in 5000 sf circular pit. Contamination to 1.5 ft.

Site 57III - Contaminated Soil Volume Estimates



Approximate Scale: 200 ft

Note: Only that portion of site 57-III that contains a contaminated area (only one sample indicated contamination) is shown.

For RI-6, LI-6, and LI-5:

57-15 at surface

Area/depth of contamination:

Assume area extends approximately 1/2 distance to uncontaminated samples, 250 x 250 ft.

Appendix C: Cost Estimates

Table C-1: Alternative 2A – UXO Clearance (Surface)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
UXO clearance from surface	acre	1,750	500	875,000
Contingency (25%)				218,750
Total Capital Cost				***$1,093,750***
O&M Costs				
Five year review (1)	hr	80	80	6,400
Contingency (25%)				1,600
Total O&M Cost				***$8,000***
Total Cost of Alternative				**$1,101,750**

(1) Cost for Five Year Review divided evenly over five years

Source: Arthur D. Little, Inc.

Table C-2: Alternative 2B – UXO Clearance to 1 Foot

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
UXO clearance to a depth of 1 foot	acre	1,750	3,000	5,250,000
Contingency (25%)				1,312,500
Total Capital Cost				***$6,562,500***
O&M Costs				
Five year review (1)	hr	80	80	6,400
Contingency (25%)				1,600
Total O&M Cost				***$8,000***
Total Cost of Alternative				**$6,570,500**

(1) Cost for Five Year Review divided evenly over five years

Source: Arthur D. Little, Inc.

Table C-3: Alternative 2C – UXO Clearance to 5 Feet

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
UXO clearance to a depth of 5 feet	acre	1,750	6,300	11,025,000
Contingency (25%)				2,756,250
Total Capital Cost				***$13,781,250***
O&M Costs				
Five year review (1)	hr	80	80	6,400
Contingency (25%)				1,600
Total O&M Cost				***$8,000***
Total Cost of Alternative				**$13,789,250**

(1) Cost for Five Year Review divided evenly over five years

Source: Arthur D. Little, Inc.

Table C-4: Alternative 3A – Containment with Soil Cover

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
UXO clearance of contaminated areas to allow for installation of cover	(1)	1	130,000	130,000
Place clean on-site soil over contaminated areas (2)				
Mobilization and demobilization	acre	7	300	2,100
Load, haul, dump, and level	cy	18,000	6	108,000
Revegetation	100 sf	2,900	26	75,400
Contingency (25%)				78,875
Total Capital Cost				***$394,375***
O&M Costs				
Five year review (3)	hr	80	80	6,400
Contingency (25%)				1,600
Total O&M Cost				***$8,000***
Total Cost of Alternative				**$402,375**

(1) Minimum cost of clearance (assumes 20 days on site required of 5-member team)
(2) Soil cover is 18 inches thick
(3) Cost of Five Year Review divided evenly over five years

Source: Arthur D. Little, Inc.

Table C-5: Alternative 3B – Containment with Engineered Cap

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
UXO clearance of contaminated areas to allow for installation of cap	(1)	1	130,000	130,000
Place clay cap over contaminated areas (2)				
Mobilization and demobilization	acre	7	300	2,100
Haul, dump, and grade	sf	290,000	0.6	174,000
Place sand and gravel over clay cap (3)				
Mobilization and demobilization	acre	7	300	2,100
Haul, dump, and grade	sf	290,000	0.3	87,000
Revegetation	100 sf	2,900	26	75,400
Contingency (25%)				117,650
Total Capital Cost				***$588,250***
O&M Costs				
Five year review (4)	hr	80	80	6,400
Contingency (25%)				1,600
Total O&M Cost				***$8,000***
Total Cost of Alternative				**$596,250**

(1) Minimum cost of clearance (assumes 20 days on site required of 5-member team)
(2) 24-inch thick clay layer
(3) 12-inch layer of sand/gravel
(4) The cost for the Five Year Review has been divided evenly over five years

Source: Arthur D. Little, Inc.

Table C-6: Alternative 4A – On-Site Treatment – Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Clear UXO	cy	32,700	12	392,400
Excavate contaminated soil	cy	32,700	8	261,600
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	32,700	4	130,800
Liner	sf	58,860	0.38	22,367
Cover	sf	75,210	0.38	28,580
Soil wash to reduce volume				
Conveyor (incl. feed hopper)	ea	1	9,600	9,600
Debris screen	ea	1	32,400	32,400
Spiral classifier	ea	1	57,600	57,600
Dewatering conveyor	ea	1	9,600	9,600
Overflow sump	ea	1	2,400	2,400
Slurry pump	gpm	210	18	3,780
Sludge pump	gpm	55	144	7,920
Settling tank	gal	12,500	2	25,000
Chemical feed system	ea	1	12,000	12,000
Filter press	cy/day	55	4,560	250,800
Recycle water tank	gal	3,100	2	6,200
Water recycle pump	gpm	210	18	3,780
Piping, electrical, and instrumentation		1	75,794	75,794
Treatability testing/engineering				100,000
Separate, stockpile, and cover washed fractions (1)				
Load, haul, and dump (2 mile round trip)	cy	6,540	4	26,160
Liner	sf	11,772	0.38	4,473
Cover	sf	15,042	0.38	5,716
Analysis of washed fractions				
Sample collection	hrs	320	30	9,600
Supervision	hrs	30	50	1,500
Sample analysis	sample	150	150	22,500
Data review and reporting	hrs	30	65	1,950
Solidification/Stabilization of contaminated fraction				
Mobilization and demobilization	ea	2	10,000	20,000
Site preparation	cy	6,540	2.4	15,696
System startup	cy	6,540	1	6,540
Treatability testing				50,000
Off-Site Landfill disposal of S/S treatment products (2)				
Mobilization and demobilization	ea	2	500	1,000
Haul and dump	cy	7,848	8	62,784
Disposal of treatment products	cy	7,848	56	439,488
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	32,700	4	130,800
Level and grade filled pits	cy	32,700	2	65,400
Vegetation	100 sf	2,900	26	75,400
Contingency (25%)				592,907
Total Capital Cost				***$2,964,535***

Table C-6: Alternative 4A – On-Site Treatment – Solidification/Stabilization (continued)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Soil wash				
Labor	hrs	9,800	45	441,000
Maintenance, power, supplies, and miscellaneous				63,162
Solidification/Stabilization				
Labor	1000 cy	6.54	27,800	181,812
Consumables	1000 cy	6.54	26,000	170,040
Equipment Rental	week	12.00	6,500	78,000
Effluent Treatment/Disposal	1000 cy	6.54	700	4,578
Analytical	1000 cy	6.54	2,100	13,734
Contingency (25%)				238,082
Total O&M Cost				***$1,190,408***
Total Cost of Alternative				**$4,154,942**

(1) Assumes the contaminated fraction is 20% of the total soil washed volume

(2) Assumes that solidification/stabilization will increase soil volume by 20%

Source: Arthur D. Little, Inc.

Table C-7: Alternative 4B – On-Site Treatment – Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Clear UXO	cy	32,700	12	392,400
Excavate contaminated soil	cy	32,700	8	261,600
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	32,700	4	130,800
Liner	sf	58,860	0.38	22,367
Cover	sf	75,210	0.38	28,580
Soil wash to reduce volume (see equipment breakout on Table C-6)				
Equipment				496,874
Treatability testing/engineering				100,000
Separate, stockpile, and cover washed fractions (1)				
Load, haul, and dump (2 mile round trip)	cy	6,540	4	26,160
Liner	sf	11,772	0.38	4,473
Cover	sf	15,042	0.38	5,716
Analysis of washed fractions				
Sample collection	hrs	320	30	9,600
Supervision	hrs	30	50	1,500
Sample analysis	sample	150	150	22,500
Data review and reporting	hrs	30	65	1,950
Solidification/Stabilization of contaminated fraction				
Mobilization and demobilization	ea	2	10,000	20,000
Site preparation	cy	6,540	2.4	15,696
System startup	cy	6,540	1	6,540
Treatability testing				50,000
On-Site disposal of S/S treatment products in active landfill (Option 1)				
Haul and dump (2)	cy	7,848	4	31,392
On-Site disposal of S/S treatment products in new landfill (Option 2)				
Engineering design and construction of new landfill (3)				1,300,000
Haul and dump (2)	cy	7,848	4	31,392
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	32,700	4	130,800
Level and grade filled pits	cy	32,700	2	65,400
Vegetation	100 sf	2,900	26	75,400
Contingency (25%) – Option 1				474,937
Contingency (25%) – Option 2				799,937
Total Capital Cost (Option 1)				***$2,374,685***
Total Capital Cost (Option 2)				***$3,999,685***

Table C-7: Alternative 4B – On-Site Treatment – Solidification/Stabilization (continued)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Soil wash				
Labor	hrs	9,800	45	441,000
Maintenance, power, supplies, and miscellaneous				63,162
Solidification/Stabilization				
Labor	1000 cy	6.54	27,800	181,812
Consumables	1000 cy	6.54	26,000	170,040
Equipment Rental	week	12.00	6,500	78,000
Effluent Treatment/Disposal	1000 cy	6.54	700	4,578
Analytical	1000 cy	6.54	2,100	13,734
Five Year Review (4)				
Data review and reporting	hrs	80.00	80	6,400
Contingency (25%)				239,682
Total O&M Cost				***$1,198,408***
Total Cost of Alternative (Option 1)				**$3,573,092**
Total Cost of Alternative (Option 2)				**$5,198,092**

(1) Assumes the contaminated fraction is 20% of the total soil washed volume
(2) Assumes that solidification/stabilization will increase soil volume by 20%
(3) New Landfill is a Subtitle D facility with 60 mil thick double synthetic liners
(4) Cost for Five Year Review has been divided evenly over five years

Source: Arthur D. Little, Inc.

Table C-8: Alternative 4C – On-Site Treatment – Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Clear UXO	cy	32,700	12	392,400
Excavate contaminated soil	cy	32,700	8	261,600
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	32,700	4	130,800
Liner	sf	58,860	0.38	22,367
Cover		75,210	0.38	28,580
Solidification/Stabilization				
Mobilization and demobilization	ea	2	10,000	20,000
Site preparation	cy	32,700	2.4	78,480
System startup	cy	32,700	1	32,700
Treatability testing				50,000
Off-Site Landfill disposal of S/S treatment products (1)				
Mobilization and demobilization	ea	2	500	1,000
Haul and dump	cy	39,240	8	313,920
Disposal of treatment products	cy	39,240	56	2,197,440
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	32,700	4	130,800
Level and grade filled pits	cy	32,700	2	65,400
Vegetation	100 sf	2,900	26	75,400
Contingency (25%)				950,222
Total Capital Cost				***$4,751,108***
O&M Costs				
Solidification/Stabilization				
Labor	1000 cy	32.70	27,800	909,060
Consumables	1000 cy	32.70	26,000	850,200
Equipment Rental	week	28.00	6,500	182,000
Effluent Treatment/Disposal	1000 cy	32.70	700	22,890
Analytical	1000 cy	32.70	2,100	68,670
Contingency (25%)				508,205
Total O&M Cost				***$2,541,025***
Total Cost of Alternative				**$7,292,133**

(1) Assumes that solidification/stabilization will increase soil volume by 20%

Source: Arthur D. Little, Inc.

Table C-9: Alternative 4D – On-Site Treatment – Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Clear UXO	cy	32,700	12	392,400
Excavate contaminated soil	cy	32,700	8	261,600
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	32,700	4	130,800
Liner	sf	58,860	0.38	22,367
Cover	sf	75,210	0.38	28,580
Solidification/Stabilization				
Mobilization and demobilization	ea	2	10,000	20,000
Site preparation	cy	32,700	2.4	78,480
System startup	cy	32,700	1	32,700
Treatability testing				50,000
On-Site disposal of S/S treatment products in active landfill (Option 1)				
Haul and dump (1)	cy	39,240	4	156,960
On-Site disposal of S/S treatment products in new landfill (Option 2)				
Engineering design and construction of new landfill (2)				1,300,000
Haul and dump (1)	cy	39,240	4	156,960
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	32,700	4	130,800
Level and grade filled pits	cy	32,700	2	65,400
Vegetation	100 sf	2,900	26	75,400
Contingency (25%) – Option 1				361,372
Contingency (25%) – Option 2				686,372
Total Capital Cost (Option 1)				***$1,806,858***
Total Capital Cost (Option 2)				***$3,431,858***
O&M Costs				
Solidification/Stabilization				
Labor	1000 cy	32.70	27,800	909,060
Consumables	1000 cy	32.70	26,000	850,200
Equipment Rental	week	28.00	6,500	182,000
Effluent Treatment/Disposal	1000 cy	32.70	700	22,890
Analytical	1000 cy	32.70	2,100	68,670
Five Year Review (3)				
Data review and reporting	hrs	80.00	80	6,400
Contingency (25%)				509,805
Total O&M Cost				***$2,549,025***
Total Cost of Alternative – Option 1				**$4,355,883**
Total Cost of Alternative – Option 2				**$5,980,883**

(1) Assumes that solidification/stabilization will increase soil volume by 20%

(2) New landfill is a Subtitle D facility with 60 mil thick double synthetic liners

(3) Cost for Five Year Review divided evenly over five years

Source: Arthur D. Little, Inc.

Table C-10: Alternative 5A – On-Site Treatment – Incineration andSolidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Clear UXO	cy	32,700	12	392,400
Excavate contaminated soil	cy	32,700	8	261,600
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	32,700	4	130,800
Liner	sf	58,860	0.38	22,367
Cover	sf	75,210	0.38	28,580
Soil wash to reduce volume				
Conveyor (incl. feed hopper)	ea	1	9,600	9,600
Debris screen	ea	1	32,400	32,400
Spiral classifier	ea	1	57,600	57,600
Dewatering conveyor	ea	1	9,600	9,600
Overflow sump	ea	1	2,400	2,400
Slurry pump	gpm	210	18	3,780
Sludge pump	gpm	55	144	7,920
Settling tank	gal	12,500	2	25,000
Chemical feed system	ea	1	12,000	12,000
Filter press	cy/day	55	4,560	250,800
Recycle water tank	gal	3,100	2	6,200
Water recycle pump	gpm	210	18	3,780
Piping, electrical, and instrumentation		1	75,794	75,794
Treatability testing/engineering				100,000
Separate, stockpile, and cover washed fractions (1)				
Load, haul, and dump (2 mile round trip)	cy	6,540	4	26,160
Liner	sf	11,772	0.38	4,473
Cover	sf	15,042	0.38	5,716
Analysis of washed fractions				
Sample collection	hrs	320	30	9,600
Supervision	hrs	30	50	1,500
Sample analysis	sample	150	150	22,500
Data review and reporting	hrs	30	65	1,950
Incinerate organic fraction (2)				
Mobilization	cy	2,943	38	111,834
Site preparation	cy	2,943	124	364,932
Trial burns	ea	1	200,000	200,000
Demobilization	cy	2,943	38	111,834
Haul incinerator residuals and metal-contaminated fraction to S/S (3)				
Load, haul, and dump (2 mi round trip)	cy	5,657	4	22,628
Solidification/Stabilization of incinerator residuals and metal-contaminated fraction				
Mobilization and demobilization	ea	2	10,000	20,000
Site preparation	cy	5,657	2.4	13,577
System startup	cy	5,657	1	5,657
Treatability testing				50,000
Off-Site Landfill disposal of S/S treatment products (4)				
Mobilization and demobilization	ea	2	500	1,000
Haul and dump	cy	6,789	8	54,308
Disposal of treatment products	cy	6,789	56	380,157
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	32,700	4	130,800
Level and grade filled pits	cy	32,700	2	65,400
Vegetation	100 sf	2,900	26	75,400
Contingency (25%)				778,012
Total Capital Cost				***$3,890,060***

Table C-10: Alternative 5A – On-Site Treatment – Incineration andSolidification/Stabilization (continued)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Soil wash				
Labor	hrs	9,800	45	441,000
Maintenance, power, supplies, and miscellaneous				63,162
Incineration				
Fuel	cy	2,943	270	794,610
Electricity	cy	2,943	40	117,720
Water	cy	2,943	10	29,430
Equipment Rental/Use (5)	week	20	17,000	340,000
Solidification/Stabilization				
Labor	1000 cy	5.66	27,800	157,267
Consumables	1000 cy	5.66	26,000	147,085
Equipment Rental	week	12.00	6,500	78,000
Effluent Treatment/Disposal	1000 cy	5.66	700	3,960
Analytical	1000 cy	5.66	2,100	11,880
Contingency (25%)				546,028
Total O&M Cost				***$2,730,142***
Total Cost of Alternative				**$6,620,202**

(1) Assumes the contaminated fraction is 20% of the total soil washed volume
(2) Assumes that organic-contaminated fraction is 45% by volume
(3) Assumes that incinerator residuals are 70% of incinerator feed volume
(4) Assumes that solidification/stabilization will increase soil volume by 20%
(5) Includes transportation and labor

Source: Arthur D. Little, Inc.

Table C-11: Alternative 5B – On-Site Treatment – Incineration and Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Clear UXO	cy	32,700	12	392,400
Excavate contaminated soil	cy	32,700	8	261,600
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	32,700	4	130,800
Liner	sf	58,860	0.38	22,367
Cover	sf	75,210	0.38	28,580
Soil wash to reduce volume (see equipment breakout on Table C-10)				
Equipment				496,874
Treatability testing/engineering				100,000
Separate, stockpile, and cover washed fractions (1)				
Load, haul, and dump (2 mile round trip)	cy	6,540	4	26,160
Liner	sf	11,772	0.38	4,473
Cover	sf	15,042	0.38	5,716
Analysis of washed fractions				
Sample collection	hrs	320	30	9,600
Supervision	hrs	30	50	1,500
Sample analysis	sample	150	150	22,500
Data review and reporting	hrs	30	65	1,950
Incinerate organic fraction (2)		6,540		
Mobilization	cy	2,943	38	111,834
Site preparation	cy	2,943	124	364,932
Trial burns	ea	1	200,000	200,000
Demobilization	cy	2,943	38	111,834
Haul incinerator residuals and metal-contaminated fraction to S/S (3)				
Load, haul, and dump (2 mi round trip)	cy	5,657	4	22,628
Solidification/Stabilization of incinerator residuals and metal-contaminated fraction				
Mobilization and demobilization	ea	2	10,000	20,000
Site preparation	cy	5,657	2.4	13,577
System startup	cy	5,657	1	5,657
Treatability testing				50,000
On-Site disposal of S/S treatment products in active landfill (Option 1)				
Haul and dump (4 mile round trip) (4)	cy	6,789	4	27,154
On-Site disposal of S/S treatment products in new landfill (Option 2)				
Engineering design and construction of new landfill (5)				1,300,000
Haul and dump (4 mile round trip) (4)	cy	6,789	4	27,154
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	32,700	4	130,800
Level and grade filled pits	cy	32,700	2	65,400
Vegetation	100 sf	2,900	26	75,400
Contingency (25%)– Option 1				675,934
Contingency (25%) –Option 2				1,000,934
Total Capital Cost (Option 1)				***$3,379,671***
Total Capital Cost (Option 2)				***$5,004,671***

Table C-11: Alternative 5B – On-Site Treatment – Incineration and Solidification/Stabilization (continued)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Soil wash				
Labor	hrs	9,800	45	441,000
Maintenance, power, supplies, and miscellaneous				63,162
Incineration				
Fuel	cy	2,943	270	794,610
Electricity	cy	2,943	40	117,720
Water	cy	2,943	10	29,430
Equipment Rental/Use (6)	week	20	17,000	340,000
Solidification/Stabilization				
Labor	1000 cy	5.66	27,800	157,267
Consumables	1000 cy	5.66	26,000	147,085
Equipment Rental	week	12.00	6,500	78,000
Effluent Treatment/Disposal	1000 cy	5.66	700	3,960
Analytical	1000 cy	5.66	2,100	11,880
Five Year Review (7)				
Data review and reporting	hrs	80.00	80	6,400
Contingency (25%)				547,628
Total O&M Cost				***$2,738,142***
Total Cost of Alternative (Option 1)				**$6,117,813**
Total Cost of Alternative (Option 2)				**$7,742,813**

(1) Assumes the contaminated fraction is 20% of the total soil washed volume
(2) Assumes that organic-contaminated fraction is 45% by volume
(3) Assumes that incinerator residuals are 70% of incinerator feed volume
(4) Assumes that solidification/stabilization will increase soil volume by 20%
(5) New Landfill is a Subtitle D facility with 60 mil thick double synthetic liners
(6) Includes transportation and labor
(7) The cost for the Five Year Review has been divided evenly over five years

Source: Arthur D. Little, Inc.

Table C-12: Alternative 5C – On-Site Treatment – Incineration and Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Clear UXO	cy	32,700	12	392,400
Excavate contaminated soil	cy	32,700	8	261,600
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	32,700	4	130,800
Liner	sf	58,860	0.38	22,367
Cover	sf	75,210	0.38	28,580
Incinerate organic soils (1)				
Mobilization	cy	14,715	38	559,170
Site preparation	cy	14,715	124	1,824,660
Trial burns	ea	1	200,000	200,000
Demobilization	cy	14,715	38	559,170
Haul incinerator residuals and metal-contaminated soil to S/S (2)				
Load, haul, and dump (2 mi round trip)	cy	28,286	4	113,142
Solidification/Stabilization of incinerator residuals and metal-contaminated soil				
Mobilization and demobilization	ea	2	10,000	20,000
Site preparation	cy	28,286	2.4	67,885
System startup	cy	28,286	1	28,286
Treatability testing				50,000
Off-Site Landfill disposal of S/S treatment products (3)				
Mobilization and demobilization	ea	2	500	1,000
Haul and dump	cy	33,943	8	271,541
Disposal of treatment products	cy	33,943	56	1,900,786
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	32,700	4	130,800
Level and grade filled pits	cy	32,700	2	65,400
Vegetation	100 sf	2,900	26	75,400
Contingency (25%)				1,675,746
Total Capital Cost				***$8,378,732***

Table C-12: Alternative 5C – On-Site Treatment – Incineration and Solidification/Stabilization (continued)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Incineration				
Fuel	cy	14,715	270	3,973,050
Electricity	cy	14,715	40	588,600
Water	cy	14,715	10	147,150
Equipment Rental/Use (4)	week	20	17,000	340,000
Solidification/Stabilization				
Labor	1000 cy	28.29	27,800	786,337
Consumables	1000 cy	28.29	26,000	735,423
Equipment Rental	week	26.00	6,500	169,000
Effluent Treatment/Disposal	1000 cy	28.29	700	19,800
Analytical	1000 cy	28.29	2,100	59,400
Contingency (25%)				1,704,690
Total O&M Cost				***$8,523,449***
Total Cost of Alternative				**$16,902,181**

(1) Assumes that organic-contaminated fraction is 45% by volume
(2) Assumes that incinerator residuals are 70% of incinerator feed volume
(3) Assumes that solidification/stabilization will increase soil volume by 20%
(4) Includes transportation and labor

Source: Arthur D. Little, Inc.

Table C-13: Alternative 5D – On-Site Treatment – Incineration and Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Clear UXO	cy	32,700	12	392,400
Excavate contaminated soil	cy	32,700	8	261,600
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	32,700	4	130,800
Liner	sf	58,860	0.38	22,367
Cover	sf	75,210	0.38	28,580
Incinerate organic soils (1)				
Mobilization	cy	14,715	38	559,170
Site preparation	cy	14,715	124	1,824,660
Trial burns	ea	1	200,000	200,000
Demobilization	cy	14,715	38	559,170
Haul incinerator residuals and metal-contaminated soil to S/S (2)				
Load, haul, and dump (2 mi round trip)	cy	28,286	4	113,142
Solidification/Stabilization of incinerator residuals and metal-contaminated soil				
Mobilization and demobilization	ea	2	10,000	20,000
Site preparation	cy	28,286	2.4	67,885
System startup	cy	28,286	1	28,286
Treatability testing				50,000
On-Site disposal of S/S treatment products in active landfill (Option 1)				
Haul and dump (4 mile round trip) (3)	cy	33,943	4	135,770
On-Site disposal of S/S treatment products in new landfill (Option 2)				
Engineering design and construction of new landfill (4)				1,300,000
Haul and dump (4 mile round trip) (3)	cy	33,943	4	135,770
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	32,700	4	130,800
Level and grade filled pits	cy	32,700	2	65,400
Vegetation	100 sf	2,900	26	75,400
Contingency (25%)– Option 1				1,166,357
Contingency (25%) –Option 2				1,491,357
Total Capital Cost (Option 1)				***$5,831,787***
Total Capital Cost (Option 2)				***$7,456,787***

Table C-13: Alternative 5D – On-Site Treatment – Incineration and Solidification/Stabilization (continued)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Incineration				
Fuel	cy	14,715	270	3,973,050
Electricity	cy	14,715	40	588,600
Water	cy	14,715	10	147,150
Equipment Rental/Use (5)	week	20	17,000	340,000
Solidification/Stabilization				
Labor	1000 cy	28.29	27,800	786,337
Consumables	1000 cy	28.29	26,000	735,423
Equipment Rental	week	26.00	6,500	169,000
Effluent Treatment/Disposal	1000 cy	28.29	700	19,800
Analytical	1000 cy	28.29	2,100	59,400
Five Year Review (6)				
Data Review and Reporting	hrs	80.00	80	6,400
Contingency (25%)				1,706,290
Total O&M Cost				***$8,531,449***
Total Cost of Alternative (Option 1)				**$14,363,236**
Total Cost of Alternative (Option 2)				**$15,988,236**

(1) Assumes that organic-contaminated fraction is 45% by volume
(2) Assumes that incinerator residuals are 70% of incinerator feed volume
(3) Assumes that solidification/stabilization will increase soil volume by 20%
(4) New Landfill is a Subtitle D facility with 60 mil thick double synthetic liners
(5) Includes transportation and labor
(6) The cost for the Five Year Review has been divided evenly over five years

Source: Arthur D. Little, Inc.

Table C-14: Alternative 6 – Off-Site Treatment and Disposal

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Clear UXO	cy	32,700	12	392,400
Excavate contaminated soil	cy	32,700	8	261,600
Analysis of soil to segregate according to hazardous characteristics				
Sample collection	hrs	160	30	4,800
Supervision	hrs	80	50	4,000
Sample analysis	sample	100	500	50,000
Data review and reporting	hrs	80	65	5,200
Haul excavated contaminated soil on-site to stockpile				
Haul and dump	cy	32,700	4	130,800
Liner	sf	58,860	0.38	22,367
Cover	sf	75,210	0.38	28,580
Haul excavated and segregated soils off-site				
Mobilization and demobilization	ea	2	500	1,000
Load	cy	32,700	2	65,400
Haul contaminated soils off-site (60 mile round trip)	cy	32,700	12	392,400
Off-Site treatment of hazardous soils (1)				
Solidification/stabilization	cy	16,350	160	2,616,000
Off-Site disposal of nonhazardous soils (1)				
Landfill	cy	16,350	56	915,600
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	32,700	4	130,800
Level and grade filled pits	cy	32,700	2	65,400
Vegetation	100 sf	2,900	26	75,400
Contingency (25%)				1,290,437
Total Capital Cost				***$6,452,183***
O&M Costs				
There are no O&M costs associated with this alternative				
Total Cost of Alternative				**$6,452,183**

(1) Assumes that 50% of soil is characterized as hazardous; 50% of soil is characterized as nonhazardous

Source: Arthur D. Little, Inc.

Table C-15: Alternative 7 – On-Site Treatment – Soil Segregation and On-Site Treatment and Disposal

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Clear UXO	cy	32,700	12	392,400
Excavate contaminated soil	cy	32,700	8	261,600
Analysis of soil to segregate according to hazardous characteristics				
Sample collection	hrs	160	30	4,800
Supervision	hrs	80	50	4,000
Sample analysis	sample	100	500	50,000
Data review and reporting	hrs	80	65	5,200
Haul excavated contaminated soil on-site to stockpile				
Haul and dump	cy	32,700	4	130,800
Liner	sf	58,860	0.38	22,367
Cover	sf	75,210	0.38	28,580
Solidification/Stabilization of hazardous soils (1)				
Mobilization and demobilization	ea	2	10,000	20,000
Site preparation	cy	16,350	2.4	39,240
System startup	cy	16,350	1	16,350
Treatability testing				50,000
On-Site disposal of S/S treatment products and nonhazardous soils in active landfill (Option 1)				
Haul and dump (2)	cy	35,970	4	143,880
On-Site disposal of S/S treatment products and nonhazardous soil in new landfill (Option 2)				
Engineering design and construction of new landfill (3)				1,300,000
Haul and dump (2)	cy	35,970	4	143,880
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	32,700	4	130,800
Level and grade filled pits	cy	32,700	2	65,400
Vegetation	100 sf	2,900	26	75,400
Contingency (25%)– Option 1				360,204
Contingency (25%) –Option 2				685,204
Total Capital Cost (Option 1)				***$1,801,021***
Total Capital Cost (Option 2)				***$3,426,021***

Table C-15: Alternative 7 – On-Site Treatment – Soil Segregation and On-Site Treatment and Disposal (continued)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Solidification/Stabilization				
Labor	1000 cy	16.35	27,800	454,530
Consumables	1000 cy	16.35	26,000	425,100
Equipment Rental	week	12.00	6,500	78,000
Effluent Treatment/Disposal	1000 cy	16.35	700	11,445
Analytical	1000 cy	16.35	2,100	34,335
Five Year Review (4)				
Data review and reporting	hrs	80.00	80	6,400
Contingency (25%)				252,453
Total O&M Cost				***$1,262,263***
Total Cost of Alternative (Option 1)				**$3,063,283**
Total Cost of Alternative (Option 2)				**$4,688,283**

(1) Assumes that 50% of soil is characterized as hazardous; 50% of soil is characterized as nonhazardous

(2) Assumes that solidification/stabilization will increase soil volume by 20%

(3) New Landfill is a Subtitle D facility with 60 mil thick double synthetic liners

(4) The cost for the Five Year Review has been divided evenly over five years

Source: Arthur D. Little, Inc.

Comment and Response Package
USEPA and DEQ Comments

Draft Final Feasibility Study For Ammunition Demolition Activity Area (OU4) at the Umatilla Depot Activity (UMDA)

Submitted to:

U.S. Army Environmental Center (USAEC), Aberdeen Proving Ground, Maryland

Revision 0
November 15, 1993

Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts
02140-2390

ADL Reference 67062

DAAA15-91-D-0016
Delivery Order No. 2

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Draft Final Feasibility Study for Ammunition Demolition Activity Area (OU4) at the Umatilla Depot Activity (UMDA)

R N Lambe 15 NOV 93
Program Manager, Robert Lambe Date

Armand A. Balasco 15 Nov. 1993
Task Manager, Armand Balasco Date

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Responses to U.S. Environmental Protection Agency (EPA) Technical Review Comments on Draft Final Feasibility Study for the Ammunition Demolition Area (OU-4) at Umatilla Depot Activity

Comment 1

Section 1.2.2.2.12, page 1-24. This section states that the UMDA has RCRA interim status for the Open Burning Tray units. Please clarify whether these units will be closing. Specify whether the units will follow the RCRA 40 CFR Part 265 closure regulations or whether they will be addressed under the CERCLA authority.

Response

Based on information provided by the Army, the cited text has been revised to include a discussion regarding the operation and closure of these units. These trays currently operate under an Air Contaminant Discharge Permit from the ODEQ. The trays will cease operation in September 1994 at which time they will be closed under the conditions of the permit. However, soil contamination at these sites will be addressed as part of the ADA operable unit in this Feasibility Study. Note that operations at Site 16 are currently conducted under the same permit and will be subject to the same closure conditions.

Comment 2

Section 1.2.3, page 1-29, first paragraph. The text states that additional sampling and analyses are being conducted; however, it is not expected that the results will significantly impact the feasibility study. A summary of the data gaps and additional investigations currently being conducted should be included in the feasibility study. If the additional data change the extent of contamination at the various sites, the contaminated soil volume estimates should be revised and included as an appendix to the feasibility study. Also, the cost estimates should be revised if the contaminated soil volumes change significantly.

Response

The cited text has been revised to reflect that additional soil sampling and analyses was conducted at Sites 15, 17, 18, and 19 in order to fill in data gaps. The results of the additional analyses are presented in Table B-2 (of Appendix B) and the revised volume and area calculations are presented in Table B-1. The resulting revised areas and volumes are presented in Table 2-8. The cost of alternative estimates have been revised to reflect the volumes and areas presented in Table 2-8.

Comment 3

Section 1.2.3, page 1-29, second paragraph. The text states that there was a suspicion that contamination had migrated through the soil to groundwater at only one site, based on a single detection in one sample. The site, well location, contaminant detected and concentration should be specified. Also, this statement is inconsistent with the site-specific information provided later in sections 1.2.3.1 through 1.2.3.17 which state that contaminants were detected in groundwater at sites 8, 13, 14, 15, 16, 18, 19, 31, 38, 41, 55, and 57. The text states that contaminants detected in groundwater included metals,

explosives, nitrite and nitrate, and volatile organic compounds. The text should list the specific contaminants of concern detected in groundwater rather than just identifying the classes of contaminants. These discrepancies and omissions should be corrected.

Response

The possible presence of contaminants in ground water is discussed more fully in Section 1.2.5.4.3. To avoid seeming inconsistency and possible confusion, the reference to the "suspicious" sample has been deleted from Section 1.2.3. Further clarification of the summary presented in Section 1.2.3.1 through 1.2.3.17 has been included in the introductory paragraph to Section 1.2.3. Specifically, reference is made to subsequent tables (Tables 1-1 and 1-2) that contain the specific contaminants of concern and related analytical results. Section 1.2.3 is provided as a brief summary of the general types of contaminants of concern that are present in soil and ground water as determined in the RI while acknowledging that more specific information and data are provided in subsequent Sections of the FS.

Comment 4

Section 1.2.3.1 through 1.2.3.20, page 1-29 through 1-31. The description of the nature and extent of contamination at each site should include the areal extent, maximum depth, and estimated volume of contaminated media.

Response

As stated in the response to Comment 3, Section 1.2.3 is provided as a general summary of the results of the RI. To clarify, the development and presentation of the extent, depth, and estimated volume of contaminated media as presented in subsequent sections of the FS are referenced in the introductory paragraph of Section 1.2.3 to allow the reader to easily access this information.

Comment 5

Table 1-2, page 1-35. It would be helpful if a column with risk-based concentrations (at an excess cancer risk level of 1×10^{-6}) could be added to the table for screening purposes.

Response

These data have been added to Table 1-2 for reference.

Comment 6

Section 1.2.5.4.2, page 1-46, bulleted list. The risk and hazard summary provided herein, lists sites with contaminant concentrations below specified risk and hazard levels. A list of sites with contaminant concentrations above the specified action levels should also be provided, since the current presentation of site risks and hazards leaves the reader guessing about which sites are contaminated and require cleanup.

Response

The cited bulleted list has been revised to include those sites at which the specified action levels are exceeded.

Comment 7

Table 1-7, page 1-48. A column should be added to this table to show the percent of risk or hazard quotient contributed by each contaminant. In addition, the table lists the risk at several sites as being zero. It is highly unlikely that the risk is zero at these sites. The zero risks should be changed to either "NC" (not calculated) because there were no toxicity values, or they should be changed to indicate that they are less than a specified risk value, for example 1×10^{-6}.

Response

A column has been added to Table 1-7 to present the percent of risk or hazard quotient contributed by the specified contaminants. In addition, the risk and hazard values presented as 0 have been revised to reflect one of the following: (1) values were not calculated due to the absence of toxicity values, (2) calculated risks were less than $1x10^{-6}$, or (3) the hazard quotient was calculated as less than $1x10^{-3}$.

Comment 8

Table 1-9, page 1-52. Several of the risk-based preliminary remedial goals listed in the table are not consistent with those provided in the human health baseline risk assessment (HHBRA). For example, the residential risk-based concentration listed for aluminum in the table is 794,000 μg/g, but the HHBRA lists a value of 274,000 μg/g. These values should be verified so they correspond to those presented in the HHBRA, or the text should explain the deviation.

Response

The PRG provided in Table 1-9 are based on values presented in the Draft Final HHBRA. The Final HHBRA was not received from the U.S. Army Environmental Center (AEC) in order to allow any revisions to be made. The Final HHBRA is currently

being forwarded by the AEC and revised pages will be issued as soon as possible. A comparison of PRG between the Draft Final and Final versions of the HHBRA indicate that the only differences are apparently for aluminum (residential - $1x10^{-6}$ scenario) and 2,4,6-TNT (light industrial - $1x10^{-5}$ and military - 1×10^{-6}, 1×10^{-5} scenarios). Note that since aluminum did not contribute to any of the risks or hazards associated with the residential use scenario, the remedial quantities and costs for cleanup to the residential level will not change from the values presented in the Final FS. Corrections, if any, due to the difference in 2,4,6-TNT values will be provided to the regulatory agencies as soon as possible.

Comment 9

Section 1.2.6, page 1-54. The first paragraph, which discusses the exposure potential for indicator species, focuses exclusively on current risks and does not mention potential future risks. The feasibility study should at a minimum discuss whether potential future exposures and risks are likely to be different from current exposures. If they are expected to be different, future exposures should be addressed.

Response

The only indicator species for which potential future exposures may differ from current exposures is the pronghorn. A discussion of this has been added to Section 1.2.6.

Comment 10

Section 2.2.2, pages 2-2 through 2-15 (see response)

Comment 11

Table 2-2, pages 2-4 through 2-9 (see response)

Comment 12

Section 2.2.2.3, pages 2-9 through 2-15 (see response)

Response

Comments 10 through 12 address inconsistencies in the presentation and evaluation of chemical, location, and action-specific ARARs. In response to these comments, Section 2.2.2 has been substantially revised. Specifically, the development, description, and presentation of the ARARs has been made consistent for each of the categories. In addition, the ARARs have been developed to address the remedial alternatives to be

considered. The use of ARARs developed during the preparation of the FS for the Explosive Washout Lagoons has been deleted and replaced with ARARs relevant to the present FS.

Comment 13

Section 2.2.2.3.1, page 2-10 through 2-13. This section addresses the applicability of RCRA 40 CFR Part 261, Subpart D listed hazardous waste codes. The first paragraph states that listed wastes may have been managed at the sites, but because the RCRA listed wastes are only listed for reactivity and the soils no longer meet the definition of reactivity, these listed waste codes are not applicable. This section should also be amended to determine the applicability of the RCRA P and U-listed waste codes for any unused pesticides that may have been disposed of at the sites...

In addition to the requirements for listed wastes, the RCRA characteristic for reactivity would be considered an ARAR for soil with explosives concentrations above 12% or unexploded ordnance, once excavated....

Response

As part of the revision of Section 2.2.2, a discussion of the applicability of RCRA P and U-listed waste codes is presented. In addition, the applicability of the characteristic for reactivity to soil and UXO is discussed.

Comment 14

Section 2.2.2.3.1, pages 2-10 through 2-13. This section addresses the applicability of RCRA 40 CFR Section 261.24 toxicity characteristic hazardous waste codes to the contaminated soils. Two toxicity characteristic wastes are identified: D006 (cadmium) and D008 (lead). A number of other toxicity characteristic constituents... are also found at the sites at very high concentrations in some instances... An explanation of the screening and elimination process applied to all toxicity characteristic constituents should be included.

Response

The discussion of applicability of RCRA to contaminated soils as presented in Section 2.2.2 has been expanded to include the potential applicability due to the presence of a number of heavy metals at the ADA. Only limited analyses were performed in the RI to determine the applicability of RCRA to heavy metal-contaminated soil. Acknowledgement of the need for further determination to assess applicability is presented in Section 2.2.2.

Comment 15

Section 2.2.2.3.1., page 2-10, last paragraph. Concentrations of lead are reported in µg/g and mg/g. This paragraph states that soil with lead concentrations of greater than 900 mg/g will be assumed to exhibit the toxicity characteristic for lead. It appears that the value should be 900 µg/g. This inconsistency should be corrected.

Response

The correct value is 900 µg/g. This typographical error has been corrected.

Comment 16

Section 2.2.2.3.2, page 2-14, second to last paragraph. This paragraph includes the Clean Air Act and Oregon Air Pollution Control regulations as ARARs. The corresponding regulations should be cited.

Response

Citations for the relevant ARARs have been included in this discussion.

Comment 17

Section 2.2.4, page 2-18, second paragraph. The remedial action objectives for the ADA are presented in this section. The second bullet states that if background or 1×10^{-6} total excess cancer risks are not feasible, excess cancer risks will be reduced to the lowest feasible level, within the range of 1 x 10-5 to 1 x 10-6. It is proposed that the final level be determined based on a cost-benefit analysis, which is not described. Since the cost-benefit analysis would affect the remedial action and overall cleanup at ADA, the criteria and evaluation method to be used for this analysis should be presented.

Response

The wording referred to in this comment has been revised to reflect that the final level will be determined based on feasibility and cost. This does not necessarily imply the performance of a formal cost-benefit analysis; however, it does allow for the decision-makers to select a proposed remedy based on the feasibility and cost as developed in the detailed analysis of alternatives.

Comment 18

Section 2.2.4, page 2-18, second paragraph. The third bullet states that the remedial objective is to remove all unexploded ordnance (UXO) from the ADA to the maximum depth possible, if feasible from a cost standpoint. Since the extent of UXO removal may

limit access to contaminated soils at depth, it is more appropriate to associate this objective with residual risks or future land uses than cost feasibility. The future land use of the ADA should be determined, and a remedial objective should be added to remediate the ADA and to address the needs of this future land use. The feasibility study could be focused on one of the four future land uses presented:...

Response

The wording of this bullet has been revised to reflect that the clearance of UXO is to be performed to the degree to minimize risks associated with future use.

Comment 19

Section 2.3.2, page 2-21, first paragraph. The text states that the estimated areas and volumes of contaminated media requiring remediation are preliminary in nature because of the absence of sufficient data to fully delineate the vertical and area extent of contamination. Although depth is estimated for the vertical extent of contamination at each site, the text does not identify the deepest sample at each site. The vertical extent of contamination could be potentially greater if the deepest sample were contaminated and the depth of this sample were used as the vertical extent of contamination. The method for determining the vertical extent of contamination should be more clearly explained.

Table 2-7 lists the depths of contaminated soil from sample results at each site. The depths range from 0 to 10 feet below ground surface (bgs). A 25 percent contingency was applied to the soil volumes estimated in Appendix B. However, assuming the same horizontal extent, applying the contingency would only account for an increase of the vertical extent of less than 1 foot at sites with contamination less than 4 feet bgs, or 2.5 feet at the site with contamination at 10 feet bgs. Therefore, the contingency factor would only account for a small increase in the estimated vertical extent of contamination, and the estimated volumes may be significantly greater because of uncertainties associated with defining the vertical extent of contamination.

Since increasing the vertical extent of contamination would greatly increase the volume of contaminated media and associated treatment costs, and may impact the alternative selection, site specific uncertainties should be provided. Then the contingencies included to account for the site-uncertainties could be evaluated.

Response

To clarify, the maximum depth to which samples were taken (samples that indicated the presence of contamination) has been added to Table 2-7. In a majority of the instances, the degree of contamination can be identified as being within the depths to which samples were analyzed. In addition, the sample depths selected during the RI were not random but selected based on visible inspection as well as the historical background of the site. It is

acknowledged that there are a few instances in which contamination was detected at the deepest sample analyzed; however, a majority of the contamination appears to be located in relatively shallow soils. It is felt that the application of an overall uncertainty factor to each site adequately accounts for variability (both areal and vertical) that might be present in this initial estimation of soil volumes to be remediated and provides for an initial estimation of volumes to allow for the conduct of the detailed analysis of alternatives and the development of comparative cost estimates.

Comment 19

Table 2-7, page 2-22. This table includes site 16 as a site with contaminated soil locations; however, the results of the human health baseline risk assessment shown in table 1-8 on page 1-50 did not indicate any risk from soil at this site. The reason for including site 16 is unclear. Either it should be removed from the table, or a rationale for including it should be provided.

Response

Site 16 is included as a contaminated soil location due to the fact that the calculated hazard quotient for non-groundwater-related pathways is seven which is in excess of one.

Comment 20

Section 2.4.2.2.7, page 2-48, second paragraph. The last sentence summarizes EPA's position on solidification and stabilization. Solidification and stabilization processes are applicable to soils contaminated with metals and other inorganics, in addition to nonvolatile and semivolatile organic compounds. EPA does not currently view the process as applicable for remediation of soils contaminated solely with volatile organic compounds, because the volatile organic compounds would be released during the mixing and curing process... This text should be supported by a published reference or revised.

Response

The cited statement was in error and has been deleted.

Comment 21

Section 3.3, page 3-4, first paragraph; Section 4.2.1.1, page 406, second bullet: Section 4.2.1.2, page 4-9, second paragraph.

Comment 22

Section 4.2.1.2, page 4-9.

Response to Comments 21 and 22

Comments 21 and 22 relate to the clearance of UXO from the ADA to a depth of 20 feet. As a result of discussions between the Army, DEQ, and EPA, this alternative has been eliminated from consideration. Clearance of UXO to depths suitable for future use assuming the application of institutional control has been retained for consideration in the FS.

Comment 23

Section 4.2.1.4, page 4-11, fourth paragraph. Based on a technology review, the feasibility study assumes that soil washing will concentrate the volume of contaminated soil to 20 percent of the original soil volume. The text should state whether site-specific soil data were considered during the analysis of soil washing to reach the assumed 80 percent volume reduction in contaminated soil...

Response

The text has been revised to reflect that the 80 percent reduction in soil volume achievable by soil washing was based on a review of the technology for use on Deactivation Furnace Site soils at UMDA. Although particle size and contaminant distribution analyses were not performed on ADA soils, it is assumed for the purpose of this evaluation that ADA soils would be similar in nature to the soils at the Deactivation Furnace Site.

Comment 24

Section 4.2.4.1, page 4-24, second paragraph.

Comment 25

Section 4.2.4.2, page 4-26, last paragraph.

Response to Comments 24 and 25

See response to Comments 21 and 22.

Comment 26

Section 4.2.7.1, page 4-44, first paragraph and Section 4.2.8.1., page 4-49, second paragraph. Alternatives 4, 5, 6, and 7 include contaminated soil excavation and segregation of hazardous and nonhazardous soils before treatment or disposal. The feasibility study should consider whether existing data could be used or additional data collected to characterize soils as hazardous or nonhazardous before excavation, and therefore eliminating the need to stockpile large volumes of excavated soils.

Response

The text has been revised to reflect that the segregation of hazardous and nonhazardous soils will be based on existing data as well as additional confirmation sampling and analyses. Descriptions of alternatives that employ segregation of soils have been revised to reflect this. Cost estimates for these alternatives have been revised to include additional costs due to sampling. In addition, it is assumed that to the maximum extent possible, segregation will occur during excavation with confirmation analyses performed after excavation.

Comment 27

Section 4.3.2, page 4-55 and 4-56, first and second bullets. The comparative analysis for compliance with ARARs should note that if UXO clearance is conducted to a depth less than the vertical extent of contamination, some of the contaminated soils will be inaccessible and remain untreated on site. Therefore, satisfying the compliance with ARARs criteria is initially dependent on the degree of UXO clearance that is implemented.

Response

The text (and related cost estimates) has been revised as appropriate to reflect that UXO clearance will be performed as necessary to permit excavation of contaminated soils.

Comment 28

Section 4.3.3., page 4-56, first paragraph. The text states that when combined with alternative 3, alternatives 4, 5, 6, and 7 would provide for permanent removal of UXO and contaminants from the ADA. Since alternatives 4, 5, and 7 include on-site solidification and stabilization or landfill disposal, contaminants would remain on site. Therefore, only alternative 6 permanently removes UXO and contaminants from the ADA.

Response

The cited text has been revised accordingly.

Comment 29

Section 5.0, Appendix C. Alternative 3 was not included in the appendix.

Response

The cited alternative has been deleted from consideration. The cost tables in Appendix C reflect each of the alternatives considered.

Comment 30

Appendix B, Site 15.

Comment 31

Appendix B, Site 16.

Comment 32

Appendix B, Site 17.

Comment 33

Appendix B, Site 19

Comment 34

Appendix B, Site 31

Comment 35

Appendix B, Site 57

Response to Comments 30 through 35

Estimation of contaminated volumes for all sites has been clarified and revised, as necessary. Appendix B now includes a graphical representation of and better rationale for the estimation of contaminated volumes.

Comment 36

Appendix C. Additional sampling will be required for site characterization or confirmation sampling during remediation. An estimate for the cost of analytical sampling required during and after remedial action should be included.

Response

Costs for additional sampling and analyses beyond that specifically presented in the FS are included in the contingency cost allowances as part of the indirect capital cost. The text has been revised to include this clarification.

Comment 37

Appendix C, Tables C-7 through C-21. Contaminated soil volumes estimated in Appendix B and summarized in Table C-8 included a 25 percent contingency factor. Cost estimates for alternatives 4, 5, 6, and 7 are based on the estimated volume plus contingency; it is estimated that a total of 26,800 cubic yards requires treatment. However, additional contingencies for loading and hauling contaminated soils are included in the cost estimates and ranged from 20 to 25 percent. It should be clarified whether these contingencies involve adjusting a clean soil cost estimate with a factor to compensate for contaminated soil or involve using an additional contingency factor. Finally, overall contingency of 25 percent is applied to the total capital costs and the total operation and maintenance costs. Although this percentage is reasonable for a feasibility study estimate, the fact that other contingencies are included makes the overall contingency allowance misleading.

Response

Appropriate revisions have been made to the text to clarify the difference between factors applied as "uncertainties" and factors applied as "contingencies." The factors applied to soil volumes reflect an allowance made for uncertainties involved in the estimation of contaminated soil volumes. Contingencies applied to the capital and operation and maintenance costs include funds to cover costs resulting from unforeseen circumstances (e.g., weather conditions, contaminant not detected during site characterization, labor strikes or delays, etc.).

Comment 38

Appendix C, Table C-7, C-8, C-13, C-14, and C-15. Treatability study testing and engineering for soil washing is estimated at $200,000.

Response

This cost was estimated in error. A revised cost of $100,000 for treatability study testing has been included in the analysis.

Comment 39

Appendix C, Table C-9, C-12, C-15, C-18, and C-21. The cost estimates for on-site disposal in a new landfill include engineering design of $800,000 and landfill construction of $500,000. Typically engineering costs approximately 15 to 25 percent of capital costs. The reference source for this estimate should be provided.

Response

This cost breakdown is in error. The total cost of design and construction of the landfill is correctly estimated at $1,300,000 based on recent experience.

Responses to Oregon Department of Environmental Quality (DEQ) Technical Review Comments on Draft Final Feasibility Study for the Ammunition Demolition Area (OU-4) at Umatilla Depot Activity

Comment 1

DEQ is uncomfortable with the basic "all or nothing" approach used in this FS. This operable unit is composed of twenty individual sites with differing contaminant profiles and different levels of risk. Yet the approach taken here is to treat the entire OU as essentially one site. Remedial alternatives are presented which only address the unit as a whole and ignore the risks of individual sites and the cost-effectiveness of cleanup at individual sites...

Response

This issue was discussed at a meeting held between EPA, DEQ, the Army, and Arthur D. Little, Inc. at Umatilla Depot Activity (UMDA) on July 20, 1993. The FS addresses a range of remedial alternatives for all sites. This provides a basis by which proposed remedies for any or all of the sites may be selected. Thus, DEQ may still propose different remedial alternatives be used for each of the sites if desired and the Army will consider DEQ's rationale.

As a result of discussions between EPA, DEQ, and the Army, sites were prioritized for clean-up at the ADA based on risk and hazard level. Highest priority sites (those with risk levels exceeding 1×10^{-4} or hazard quotients exceeding 1 have been selected for remediation and will be presented in the proposed plan. To support the proposed plan, Section 4.3.8 of the FS addresses the soil volumes, risk levels, and costs to remediate the priority sites.

Comment 2

At an estimated cost of $516,000 per acre, UXO clearance to a depth of 20 ft. does not appear to be cost effective...Accordingly, DEQ believes this option should be eliminated from consideration...

Response

The clearance of UXO to a depth of 20 ft. has been eliminated as a final alternative. The development of costs and impacts of clearance to that depth has been retained in the FS for reference.

Comment 3

Currently, this FS includes 22 Alternatives, considering all the variations of Alternatives 2, 4, 5, and 7 (Alternative 3 is not counted, since it is not a stand alone alternative). This is far too many. A more thorough screening out of options that are more costly than ones which provide similar results should be performed. Options which could be eliminated include off-site disposal, which in every case is more costly than on-site disposal in the active landfill; construction of a new landfill, which in every case is more costly than use

of the existing active landfill; treatment of all excavated soil, which in every case is more costly than equivalent soil washing or soil segregation options; and soil washing, which is more costly than soil segregation.

Response

This issue was discussed at a meeting held between EPA, DEQ, the Army, and Arthur D. Little, Inc. at Umatilla Depot Activity (UMDA) on July 20, 1993. The FS presents an analysis of a broad range of alternatives in order to provide a solid basis for decision-making. The detailed analysis of a number of the alternatives was required in order to determine their feasibility based on cost. In view of the extensive FS work performed, it is preferable to the Army to retain the documentation of all the alternatives in the FS. The various cost effects were not known in the early stages of the FS so certain alternatives (e.g., off site disposal) could not have been accurately screened.

Comment 4

Section 1.2.5, page 1-32. Define "RA" and provide reference.

Response

This comment was addressed as requested.

Comment 5

Section 1.2.5.1, page 1-32, last bullet. Shouldn't Site 8 be added to this list (see Section 1.2.3.2, page 1-29)?

Response

The summary of contamination for Site 8 as presented in Section 1.2.3.2 was in error. This has been revised to reflect the contamination of soils at Site 8 with metals.

Comment 6

Table 1-2, page 1-35. The abbreviations "ND" and "NA" should be inserted where appropriate, to distinguish between contaminants that were not detected and those not analyzed.

Response

The abbreviations NA (Not Analyzed at this depth) and NDB (No Samples Detected above Background) have been used where appropriate in Table 1-2 to distinguish between contaminants not detected and contaminants not analyzed.

Responses to Oregon Department of Environmental Quality (DEQ) Technical Review Comments on Draft Final Feasibility Study for the Ammunition Demolition Area (OU-4) at Umatilla Depot Activity

Comment 7

Table 1-2, page 1-37. The summary for Site 21 conflicts with the summary presented in Section 1.2.3.10, page 1-30.

Response

The summary of contamination for Site 21 as presented in Section 1.2.3.10 was in error. This has been revised to reflect the lack of contaminants in soils at Site 21.

Comment 8

Section 1.2.6, page 1-51, second paragraph. Delete "A" from the reference number.

Response

This typographical error has been corrected.

Comment 9

Section 2.2.2.1, page 2-2, last paragraph. The reference number should be 19, not 20.

Response

This reference now correctly identifies the Oregon Remedial Action Rules (due to the addition of an earlier reference, the reference number is now correctly 20).

Comment 10

Table 2-1, page 2-3. Under RCRA Land Disposal Restrictions, Synopsis, correct typo (generate).

Response

This table has been revised.

Comment 11

Section 2.2.2.1, page 2-4, first bullet. Add "if applicable" after the OAR number. See comment number 16.

Response

This addition has been made.

Comment 12.

Section 2.2.2.3.1, page 2-10. There are no RCRA listed wastes associated with UMDA activities. However, certain wastes may be designated as RCRA characteristic wastes because of reactivity or toxicity. Accordingly, the first paragraph in this section should be revised to reference wastes contaminated with explosives and/or metals "exhibiting the characteristics of reactivity or toxicity" instead of "listed because of reactivity." Also, change "RCRA-listed wastes" to "RCRA wastes." Finally, in the second paragraph, the reference should be to number 21, not 20.

Response

Section 2.2.2.3 has been revised to address all of the above comments.

Comment 13

Table 2-3, pages 2-11 and 2-12. Change "hazardous waste" to RCRA hazardous waste" throughout the discussions of 40 CFR Parts 262, 263, and 264 (note Part 268 is correct as written). It is important to clarify that these requirements are only applicable to specific wastes under RCRA, and not to all wastes which may be considered "hazardous."

Response

Table 2-3 has been revised to reflect these changes.

Comment 14

Section 2.2.2.3.2, page 2-13, first paragraph. In the third sentence, the reference number should be 20, not 21.

Response

This section has been revised and the references have been corrected.

Comment 15

Section 2.2.4, page 2-15. Change the last two sentences to read as follows: "The numerical....remedial goals as well as background values. For reference, state-established cleanup levels and certified reporting limits...." See comment number 16.

Comment 16

Table 2-5, page 2-17. Oregon's Numerical Soil Cleanup Levels have been incorrectly used in this table. First, use of these standards is not appropriate, because some of the contaminants of concern exist in groundwater, and because not all of the contaminants of

concern are included on the soil cleanup table. Second, even if these standards are just listed as a point of reference as suggested in comment number 15, incorrect values have been used. The cleanup values listed are from Appendix 1 of the rules. These soil values are to be used only in conjunction with the accompanying leachate or groundwater reference concentration (i.e., soil values are not stand alone cleanup standards). The appropriate values to use (for reference only) are the values on Table 1 of the rules. These values are stand alone cleanup levels for organics, but there are no inorganics on this table.

Comment 17

Section 2.2.4, page 2-18. In the first paragraph, change the first sentence to read: "It should be noted that state-established cleanup levels for organics are not applicable and are provided only for reference." In the third paragraph, delete the last sentence (i.e., do not use DEQ's numerical standards to set cleanup levels for this OU).

Comment 18

Table 2-6, page 2-19. Delete ONSCL values and replace with risk-based values (see comments number 16 and 17).

Response to Comments 15, 16, 17, and 18

In accordance with the above comments, the Oregon Numerical Soil Cleanup Levels are no longer used to set cleanup levels for this OU. References to these incorrect values have been deleted. The appropriate state ARAR (Oregon Hazardous Substance Remedial Action Rules) are presented in Section 2.2.2.1.

Comment 19

Section 2.4.2.1, page 2-39. In the first paragraph, change "explosives interest" to "explosives of interest". In the second paragraph, change "explosives moisture" to

"explosives mixture". In the fourth paragraph, change "involved procedures" to "involved in procedures".

Response

Appropriate corrections have been made to the text as noted.

Comment 20

Section 3.2, pages 3-1 through 3-4. What is the basis for the assumption that the entire 1,750 acre ADA may contain UXOs? Based on the available historical records, it appears that open detonation and firing range activities, which could generate UXOs, were restricted to a relatively few, distinct areas within the ADA. Given the significant costs of

UXO clearance, some rationale should be presented to justify the need for clearing the entire ADA area.

Response

Despite the possibility that the presence of UXO may be limited to certain areas of the ADA, the exact locations and frequency of UXO are unknown. Metallic items appear to have been fairly widely dispersed throughout the area. Because of the unknowns associated with the presence of UXO and in order to insure that adequate levels of protection are provided by UXO clearance, requirements for clearance are conservatively assumed to encompass the entire 1750-acre site. This discussion is presented in Section 4.2.3.1 of the FS. [Note that if the Army must certify the entire ADA as cleared of UXO to a certain depth, it may not be prudent (or possible) to try to show that certain areas have never been used.]

Comment 21

Table 3-1, page 3-2, and Section 3.3, page 3-4. Based on the end-use descriptions in Table 2-4, page 2-16, wouldn't Alternative 3 (i.e., clearance to 5 ft.) also provide for future agricultural use of the property?

Response

The FS has been revised in such a manner that Alternative 3, as presented in this draft (i.e., Institutional Control, UXO Clearance, and Soil Removal) is no longer an alternative under consideration. The cost for a range of UXO clearance levels and supporting information is still included in the FS.

Comment 22

Section 4.2.1.6, page 4-19, first paragraph. The final closure plan for the active landfill now provides for it to remain open for receipt of non-hazardous cleanup wastes until March 1998.

Response

This correction has been made to the text with reference.

Comment 23

Section 4.2.4.2, page 4-26, Implementability. The text on page 4-9, first full paragraph, indicates that clearance to 20 ft. has not been demonstrated.

Response

This comment is no longer relevant due to the elimination of the 20-foot clearance as an alternative under consideration.

Comment 24

Table 4-2, page 4-28. Change "Annual Cost" to "Total Cost".

Response

This table has been revised.

Comment 25

Section 4.2.7.2, page 4-47, second paragraph. Disposal of wastes in a properly designed and constructed landfill would provide some reduction in contaminant mobility. This comment also applies to the third paragraph on page 4-48.

Comment 26

Section 4.3.1., page 4-55, second paragraph. See comment number 25.

Comment 27

Section 4.3.4, page 4-57, last paragraph. It should be stated that Alternative 2 would result in a reduction in contaminant mobility.

Response to Comments 25, 26, and 27

These revisions have been made to the text as specified.

Comment 28

Section 4.3.6, page 4-58, first paragraph. See comment number 23.

Response

See response to comment number 23.

Comment 29

Appendix C - General Comments ...

Response

The general comments for Appendix C address various inconsistencies and need for clarification of some line items in Appendix C. This appendix has been revised to correct the inconsistencies and errors. The cost of treatability studies for soil washing have been reduced to $100,000 to reflect DEQ and EPA comments.

Comment 30

Table C-7. The text (page 4-16) describes the use of a plastic-lined trench as a stockpile area for stabilized soils. The capital costs for preparation and materials for the stockpile area are not included on this table. This comment also applies to other alternatives where soil solidification/stabilization is proposed.

Response

As shown in Section 4.2.1.5, the text addressing the method of managing the stabilization/solidification treatment products prior to their disposal has been revised/corrected. The revision reflects that the treatment products are discharged to a dump truck or transportable container for transport to the final disposal area.

Comments 31 through 37

These comments address inconsistencies and need for clarification of cost items presented in Appendix C. The tables in Appendix C have been revised accordingly to address all inconsistencies and needed clarifications.

Comment 38

Tables C-19, C-20, and C-21. What are the estimated analytical costs to determine if soil is RCRA Hazardous Waste or not?

Response

The cost for these analytical determinations are presented in the revised Appendix C tables.